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Economic Values For Evaluation of Federal Aviation Administration Investment and Regulatory Programs

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Ward Keech, Stefan Hoffer, Calvin Timmerman, Frank Beradino

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16. Abstract

Drawing on economic theory, empirical investigations and data from government, private and academic literature, this report revises economic values commonly used by the Federal Aviation Administration (FAA) in the evaluation of investment and regulatory programs. The[illegible] include the value of time in air travel, the value of a sta[illegible]cal life, unit costs of statistical aviation injuries, air[illegible] capacity and utilization factors, aircraft variable oper[illegible] costs, unit replacement and restoration costs of damaged aircr[illegible], [illegible]t penalty costs, and probabilities of third-party damage.

These values, often referred to as "critical values," provide the bases upon which the effectiveness of the aviation system or changes therein may be denominated and assessed in monetary terms. FAA decisionmaking should ideally discriminate among alternative investment and regulatory actions according to whether or not they entail socially and economically acceptable uses of user and general taxes. Conceptually, these values can be thought of as measures of the minimum dollar sacrifice that society and users are or should be willing to make to provide for the sustained or improved effectiveness of the aviation system.

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EXECUTIVE SUMMARY

Drawing on economic theory, empirical investigations and data from government, private and academic literature, this report updates economic values commonly used by the Federal Aviation Administration (FAA) in the evaluation of investment and regulatory programs. These include the value of time in air travel, the value of a statistical life, unit costs of statistical aviation injuries, aircraft capacity and utilization factors, aircraft variable operating costs, unit replacement and restoration costs of damaged aircraft, weight penalty costs, and the probability of third-party damage.

These values and others, often referred to as "critical values," provide the bases upon which the effectiveness of the aviation system or changes therein may be denominated and assessed in monetary terms. FAA decisionmaking should ideally discriminate among alternative investment and regulatory actions according to whether or not they involve socially and economically acceptable uses of user and general taxes. Conceptually, these values can be thought of as measures of the minimum dollar sacrifice that society and users are or should be willing to make to provide for the sustained or improved effectiveness of the aviation system.

Whereas some critical values are readily measurable by reference to the marketplace, others must be imputed and are subject to estimating error because of state-of-the-art and data limitations. Nevertheless, analyses must be conducted and decisions made. Even imputed dollar estimates of benefits gained or foregone will guide and facilitate rational and intelligent FAA decisionmaking. This basis is obviously preferable to decisionmaking based merely on subjective or intuitive judgment.

The critical values developed in this report are summarized below in terms of 1987 dollars (with a few exceptions related to military aircraft for which values are given in estimated 1988 dollars). These are summary values only. Analysts and other users should refer to the text of the report for further detailed values. These values are expected to change with the passage of time because of anticipated price and income level changes and, to a lesser extent, future theoretical and empirical research. Periodic revisions of this report will attempt to account for such changes and advancements. Between interim revisions, users should update these values to future year dollar levels based on the methodology outlined in Section 9 of this report. Section 9 also presents recommended rounding conventions.

NATURE OF CRITICAL VALUE	1987 VALUE AFTER ROUNDING (Except Where Noted)
Value of Time in Air Travel Per Hour	
Business Trips	$ 37.00
Non-Business Trips	$ 32.00
Average for All Trips	$ 34.00

NATURE OF CR[illegible]AL VALUE	1987 VALUE AFTER ROUNDING (Except Where Noted)
Value of a Statistical Life	$ 1,740,000
Unit Costs of Statistical Aviation Injuries	
Minor Injury (AIS 1)	$ 2,300
Serious Injury:	
Moderate Injury (AIS 2)	$ 22,000
Serious Injury (AIS 3)	$ 150,000
Severe Injury (AIS 4)	$ 500,000
Critical Injury (AIS 5)	$ 1,560,000
Maximum Injury (AIS 6)	$ 1,790,000
Weighted Average	$ 740,000
Other Injury Classifications:	
Critical Spinal Cord Injury Resulting in Quadriplegia	$ 2,210,000
Critical Head Injury Resulting in Total Disability	$ 2,460,000
Critical Burn Injury	$ 2,400,000
Aircraft Capacity and Utilization Factors	
Air Carrier Weighted Averages (Using Total Fleet Airborne Hours)	
Seat Capacity	170.8 Seats
Crew Members	7 Crew
Cargo Capacity	22.3 Tons
Passenger Load Factor	61.6 Percent
Cargo Load Factor	52.7 Percent
Daily Utilization	8.4 Hours
Off-On Speed	429 mph
General Aviation Weighted Averages (Using Hours Flown)	
All GA Maximum Seating Capacity	5.3 Seats
GA Air Taxi and Commuter Seating Capacity	9.6 Seats
All GA Passenger Load Factor	52.8 Percent
GA Air Taxi and Commuter Passenger Load Factor	45.9 Percent
All GA Useful Load	1,937 Pounds
GA Air Taxi and Commuter Useful Load	3,325 Pounds

NATUE OF CRITICAL VALUE		1987 VALUES AFTER ROUNDING (Except Where Noted)
Aircraft Total Variable Operating Costs (Weighted Averages Using Hours Flown)	Per Block Hr.	Per Airborne Hr.
Air Carrier	$ 1,219	$ 1,465
All General Aviation (Including Air Taxi)		$ 105
General Aviation Excluding Air Taxi and Commuter		$ 85
General Aviation Air Taxi and Commuter Only		$ 220
Military Aircraft (1988 Value, $1988)		$ 1,049

Unit Replacement and Restoration Costs of Damaged Aircraft	Replacement Costs	Restoration Costs
Air Carrier (Population Average)	$ 8,871,000	$ 1,153,000
General Aviation (Population Average)		
All GA (Including Air Taxi)	$ 74,000	$ 13,000
GA Excluding Air Taxi and Commuter	$ 66,000	$ 12,000
GA Air Taxi and Commuter Only	$ 250,000	$ 37,900
Military (1988 Values)	$ 8,352,000	$ 1,086,000
Accident Investigation Costs Per Accident, Weighted Averages		
Air Carrier Average, Major and Regular Investigations		$ 349,000
General Aviation, NTSB and FAA Regular Investigations		$ 5,000

Models to Estimate Weight Penalties Due to Regulatory Changes

Lotus 1-2-3 models based on estimations using 1985 operating cost and performance data are provided to allow the direct calculation of increased operating costs due to aircraft weight increases. Models are provided for air carrier, commuter, and general aviation aircraft.

SECTION 1: VALUE OF TIME IN AIR TRAVEL

A. Introduction

The purpose of this section is to provide revised estimates of the value of travel time for use in evaluating FAA investment and regulatory programs which affect time spent in air travel. Since speed is a principal advantage of air transportation over alternative modes, the value of time can be important in determining whether investments and regulatory decisions affecting the aviation system are economically rational.

Travel time can be "saved" in two ways. First, reduced en route time makes more time available at the origin or destination of a trip. Second, time is saved for many travelers if scheduled operations are made more reliable. More reliable schedules reduce the allowances for delay which prudent travelers make in planning trips. Conceptually, the value sought here is the gain to travelers, to other individuals, and/or to society resulting from reduced travel time requirements because of decreased en-route time and more reliable schedules.

Because available time is limited, it is an economic resource and has value. Time spent in business travel has value to an employer because the employee could otherwise spend time in more productive work activities. Similarly, time spent in nonbusiness or leisure travel has value because the traveler could alternatively use such time in other activities from which he or she may derive utility.

The value of travel time saved is likely to depend on both traveler and trip characteristics. Income, age, employment status and family composition are traveler characteristics that may affect passengers' valuation of travel time. Trip characteristics that may affect the value of time include trip purpose, trip length, time of day, day of week and season. In addition, it has been argued that the per unit value of time depends on the amount of time saved.

The most recent theoretical and empirical literature suggests that both traveler and trip characteristics have an effect on the value of travel time. Individuals purchase goods and services and spend time in activities in order to maximize their total utility subject to income and time constraints. Time spent traveling is an intermediate activity used to produce economic goods from which individuals derive utility. For example, the time spent traveling to a vacation site is an intermediate activity required to "produce" leisure activities enjoyed during the vacation. Disutility to delay suffered by an individual, therefore, will depend upon trip purpose and other demographic characteristics. As these characteristics vary, the value of time also varies.

The values of traveler time shown in this section are based upon the most recent theoretical and empirical literature. They vary by trip purpose and user group. A single average value of $33.85 per hour (in 1987 dollars) is

also derived in this section (or $34.00 after applying the recommended rounding convention).

Immediately below, the theory of the value of travel time is discussed. After this, the results of empirical studies which have attempted to estimate the value of travel time are described. Finally, revised estimates of air travelers' value of time for use in FAA investment and regulatory decision-making are presented.

B. Theory of the Value of Travel Time

In the past, it has sometimes been argued that the wage rate can be taken as a measure of the value of travel time saved for both business and nonbusiness travel. The theoretical arguments on which this hypothesis is based are reviewed below. Following this, recent developments towards a more generalized theory of the value of travel time are described.

1. Value of Travel Time and the Wage Rate

One basis for valuing time in business travel relies on the theories of marginal productivity and competitive markets. This theory holds that a profit-maximizing firm in a competitive market will be in equilibrium when the marginal revenue product of a factor of production equals its price. Accordingly, the firm will hire labor up to that point beyond which it is no longer worthwhile; that is, where the marginal revenue product of labor equals the earnings rate. The value of an employee's time to the firm, therefore, is the employee's earnings rate.

This approach to valuing business travel time has been criticized on several grounds. In reality, many markets differ substantially from the perfectly competitive model which underlies the theory. Moreover, schedule rigidities and difficulties in transferring time saved to other activities can, in some cases, cause the value of time to diverge from the business traveler's wage rate. Finally, the theory does not explicitly consider the value of time saved to the employee because of factors such as discomfort in travel or disutility associated with work.

One argument for valuing time in nonbusiness travel rests on consumer choice theory. This theory holds that, in the absence of any market imperfections, consumers will allocate their time between alternative activities such that the marginal value of time is equal in each activity. As an example, this theory implies that a consumer will be in equilibrium when the marginal value of time spent in travel equals his or her marginal value of time spent at work. If the earnings rate reflects the marginal value of time spent at work, then it follows from this argument that the earnings rate is also a measure of the value of time in travel.

This theory on the equivalence of the wage rate and the value of nonbusiness travel time has also been criticized. In particular, the theory fails to consider institutional and other constraints that the consumer faces

in allocating time across alternative activities. The theory also ignores disutility associated with travel and worktime activities.

2. General Theory of the Value of Time

Recent attempts to develop a more general theory of time have considered some of the weakness in the theories described above. This general theory, which employs the household production function approach, is based on the earlier works of Becker[1] and De Serpa[2] and more recent contributions by Bruzelius[3] and Truong and Hensher.[4]

Under the household production function approach, it is assumed that individuals purchase goods and services and spend time in activities such that total utility is maximized subject to income and time constraints. Individuals spend money on intermediate goods and services and time in intermediate activities to produce economic goods from which they receive utility. Time spent traveling to a vacation site, for example, is an intermediate activity required to "produce" pure leisure activities enjoyed during the vacation.

Individuals are willing to pay for reductions in minimum time requirements for intermediate activities because the time saved can be transferred either to pure leisure activities, (from which utility is derived) or alternatively, to work-time activities (which provides additional income). If travel is regarded as an intermediate activity, then the value of travel time saved can be measured as passengers' willingness-to-pay for reductions in the minimum travel time requirements. This value is precisely the measure that is appropriate for evaluating the benefits associated with time-saving improvements in air travel.

The general theory of the value of time makes it possible to derive explicit expressions for the value of travel time saved. This theory accounts for disutility associated with travel and work as well as institutional minimum work-time requirements (e.g., the forty-hour work week). The following two equations, which can be derived as a solution to the constrained utility maximization problem, show the relationship between the value of travel time saved and the traveler's wage rate:

(1) Value of Travel Time Saved = Resource Value of Time -
Value of Time in Travel

(2) Resource Value of Time = Wage Rate +
Value of Time at Work +
Value of Decrease in Minimum
Work-Time Requirement

The first equation states that the value of travel time saved depends on the "resource value of time" and the "value of time in travel." If the traveler suffers disutility from travel, for example, because discomfort or fear of an accident, then the value of time in travel will be negative and, as a result, the value of travel time saved will exceed the resource value of time.

The resource value of time depends on the wage rate, the "value of time and work" and the "value of a decrease in the minimum work-time requirement." If the individual suffers disutility at work, the value of time at work will be negative. If minimum work-time constraints are binding, meaning that the individual would choose to work fewer hours if he or she were free to do so, the value of a decrease in the minimum work-time requirement will be positive.

In summary, it is possible for the resource value of time to be greater or less than the wage rate. Moreover, even if the resource value of time and the wage rate were equal, the value of travel time saved will differ from the wage rate if the value of time in travel is not zero. In short, the theory concedes that the equivalence of the value of travel time saved and the wage rate cannot be established a priori. As a result, the relationship between these two measures must be established empirically.

C. Empirical Approaches to the Valuation of Time in Air Travel

Over the past few decades, a wide range of values of time in air travel have been used in applied analyses. A representative sample of these values is reported in Table 1. Many studies did not involve independent research on the value of time in air travel, but rather, simply accepted values which were thought to be representative of current thinking and opinion.

In general, the various techniques that have been developed to estimate empirically the value of time in travel can be classified into two approaches: the labor product approach and the willingness-to-pay approach. Both approaches are briefly described below. In addition, some of the more notable contributions to empirical research on the value of time in air travel are reviewed.

1. Labor Product Approach

The labor product approach is based on the notion that individuals with unconstrained labor-leisure choices will be best off when they allocate their time between activities in such a manner that the value of the last hour of time spent in each activity equals their earnings rate. On this basis, the labor product approach estimates the value of time as the contribution to the national product per employee work hour.

The total contribution of labor can be measured as gross national product (GNP) minus capital consumption allowances, indirect business taxes, rental income, net interest, corporate profits before taxes and inventory reductions. The quotient of labor's total contribution divided by total labor hours represents the average hourly contribution of labor to the national product. Since labor is presumed to be allocating its time between work and other activities in such a manner that the marginal value of time spent in each is equal, the value of a unit of time spent in any activity is equal to the average hourly contribution of labor to the national product.

Table 1

APPLIED VALUES OF TIME IN AIR TRAVEL

Study	Year	Value of Time in Business Travel	Value of Time in Nonbusiness Travel
Systems Analysis and Research Corporation	1964	1 x income	1 x income
Systems Analysis and Research Corporation[5]	1966	Incremental % per work hour:2.5 - 3.0 x earnings rate	"Not feasible"
McDonnell Aircraft Corp.	1966	1 x earnings rate	$1.00/hour
American Aviation	1966	2.5 x earnings	Not noted
Boeing-SST (FAA, 1967)	1966	1 x income	1 x income
Lockheed-SST (FAA, 1967)	1966	2 x earnings rate	1 x after-tax income
Institute for Defense Analysis-SST[6]	1966	1 x earnings rate	1 x earnings rate
FAA-SST	1967	1.5 x earnings rate	1 x earnings rate
Boeing-V/STOL	1967	1 x income	1 x income
Reuben Gronau Ph.D. dissertation	1967	.40-.45 x earnings rate	No "systematic relationship"
Charles River Associates-SST[7]	1969	1.5 x earnings rate	1.5 x earnings rate
Reuben Gronau[8]	1970	1.15-1.25 x earnings rate	No "systematic relationship"
Arthur DeVany	1971	1 x earnings rate	1 x earnings rate
Various FAA Facilities and Equipment Establishment Criteria and special analyses	1974 - 1988	1 x earnings rate	1 x earnings rate
Alan Grayson[9]	1981	.61 x earnings rate	2.14 x earnings rate
Morrison and Winston[10]	1985	.85 x earnings rate	1.49 x earnings rate
Pickrell[11]	1987	1.64 x earnings rate	.21 x earnings rate

To illustrate using 1987 preliminary national income and product accounts, the GNP in 1987 totaled $4,486.2 billion. Subtracting capital consumption allowances, indirect business taxes, rental income, net interest, corporate profits before taxes and reductions in inventory yields the total contribution of labor to the national product, or approximately $2,992.0 billion. The total labor hours in 1987 is the product of the employed labor force (114,177,000), the average work week (34.8 hours) and the number of weeks per year, or 206.6 billion hours.[12] The average hourly contribution of labor to the national product is found by dividing the total gross contribution of labor to the national product by total labor hours which is about $14.48 per hour.

The shortcomings of this approach are obvious. In reality, most individuals do not have unconstrained labor-leisure choices, because of institutional work hour standards. In addition, labor's average product does not necessarily equal its marginal product. The approach undoubtedly understates the value of time of air travelers because their average hourly earnings are higher than that of the population as a whole. It is further deficient in that it does not account for the value of time of individuals whose productive activity is not measured in the national income and product accounts (e.g., retirees, housewives, students, children, etc.).

2. Willingness-To-Pay Approach

Both direct and indirect approaches have been applied in attempts to estimate travelers' willingness-to-pay for travel time saved. The direct willingness-to-pay approach involves direct inquiry of travelers' preferences and choices through the use of interviews or questionnaires, while the indirect willingness-to-pay approach deduces the value of time from observation of travelers' revealed preferences for alternative modes or routes of travel. Preferences shown by travelers in making choices between different combinations of travel time and costs associated with an alternative provide a basis for inferring their willingness-to-pay for travel time saved.

Because willingness-to-pay has the virtue of covering the value of time in travel for both purposes (business and nonbusiness trips) it provides a comprehensive measure of the value of time saved. To date, there have been relatively few applications of the direct willingness-to-pay approach to valuing the time of air travelers. This is presumably attributable to the inherent weaknesses of interviews and questionnaires. People may be unable to deal with the value of time in the abstract, resulting in responses which may be biased or different from what their actual behavior might be.[13] The remainder of this discussion addresses typical applications of the indirect willingness-to-pay or revealed preference approach to valuing travel time.

Two early studies that employed the indirect willingness-to-pay approach, by DeVany[14] and Gronau,[15] are well known. DeVany's estimate of the value of time for air travelers is based on derived elasticities of demand for air travel. Using actual fares paid by air travelers between different city pairs and estimates of mean fare and time elasticities, DeVany estimated the value of time of air travelers in 1968 at $7.28 per hour. His estimates for coach and first class air travelers in 1969 from elasticity findings of Brown and Watkins[16] were $8.09 and

$11.97 respectively. The similarity between his findings and the average wage rate of airline passengers prompted DeVany to suggest that "air travelers value their time at their wage."

Gronau, relying on the work of Becker,[17] used data from a New York Port Authority survey (conducted in 1963 and 1964) to estimate a series of regression equations with arbitrary values of time. He obtained estimates of both price and income elasticities by selecting the value of time which yielded the highest explanatory power. The highest explanatory power obtained for business travelers occurred for a value of time between 1 and 1.25 times average earnings. Gronau's findings for the value of time of nonbusiness travellers were inconclusive.

The DeVany and Gronau studies have some common deficiencies. First, there is some question as to whether price elasticities or regression coefficients are constant over time. Second, neither study considers several factors affecting the demand for air travel such as convenience, comfort, safety, the prestige associated with the mode, substitute modes of travel, and other demand determinants. In addition, DeVany's estimates are based on mean elasticities, but as trip length increases, fare elasticity increases and time elasticity decreases.

More recently, Pickrell,[18] Morrison and Winston,[19] and Grayson[20] have employed more sophisticated statistical techniques to estimate air travelers' willingness-to-pay for time saved. Each of these studies uses different samples of trips taken from the 1977 Census of Transportation National Survey. Multinomial logit models are estimated from travelers' observed choices from a set alternative modes (which include automobile, bus, rail and air).

Estimates of the value of travel time saved are measured as travelers' marginal rates of substitution between trip time and trip cost. Marginal rates of substitution are computed from the coefficients of the estimated logit functions. Because this approach considers alternative modes in the traveler's choice set, the characteristics of air travel that affect relative demand are considered implicitly.

Pickrell's study is based on a sample of about 2700 person-trips over the 46 routes most frequently reported in the survey. Approximately 1,100 of these trips were taken for business purposes. The value of time saved for air travelers is estimated as 1.64 and .21 times the wage rate for business and nonbusiness trips, respectively. Pickrell's estimate of the value of time saved for nonbusiness travelers, relative to the wage rate, is substantially lower than the estimates reported by both Morrison and Winston, and Grayson.

The Morrison and Winston estimates are based on a sample of 1,893 household trips over 607 different city pairs for nonbusiness and 2,325 business trips over 360 city pairs. Estimates of nonbusiness travelers' value of time are obtained from "nested" choice models. Specifically, decisions regarding the choice of the destination, the selection of the mode, and whether to rent an automobile at the destination are modeled jointly in the nonbusiness trip model. Morrison and Winston estimated the value of time saved for business air travelers at .85 times

the wage rate. Their comparable estimate for nonbusiness travelers is 1.49 times the wage rate.

Two samples are employed in the Grayson study. The first includes 1,658 trips over the 46 routes that were most heavily sampled in the National Transportation Survey (these generally correspond to the routes having the most person-trips). The second sample consists of 1,062 trips along the 42 routes over which the greatest number of passenger miles were traveled. Grayson reports estimates of the value of time saved at .61 and 2.14 times the wage rate respectively, for business and nonbusiness air traveler.

The recent estimates of the value of time saved for air travelers reflects a relatively broad range, especially for nonbusiness trips. This range of values is evident even in the three most recent studies reviewed above, even though similar methods and data from the same survey were employed. Some of the variability in the estimates could be due to the use of different samples, suggesting that value of time saved varies across city-pairs because of differences in unmeasured traveler and trip characteristics. In any event, considerable uncertainty in valuing travel time saved still exists.

3. Empirical Evidence on the Effects of Travelers and Trip Characteristics

As was noted earlier in this section, both traveler and trip characteristics may affect the value of time saved in air travel. Several of the studies reviewed above report estimates of the value of time saved by trip purpose and by travelers' earnings rates. The empirical research to date, however, does not permit practical and meaningful segmentation by other characteristics.

For the most part, the effects of individual traveler and household characteristics on the value of time saved have not been studied for U.S. air travelers. Morrison and Winston[21] tested and rejected the hypothesis that the number of young children and trip distance jointly affect air travelers' willingness-to-pay for time saved.

MVA Consultancy[22] found that for long distance trips, retired travelers and students value time less than full-time workers. They also found that travelers accompanied by young children and passengers making trips on Fridays place higher values on time saved. This study, however, does not include any U.S. travelers and it excludes air travelers altogether. Practical methods for integrating these results with the available estimates for U.S. air travelers are unavailable.

It has been argued that small time savings are worth less per unit of time saved than larger savings, either because travelers have difficulty perceiving small time savings or because some minimum block of time is required for "useful" activities. Bruzelius,[23] however, demonstrates that even unperceived time savings have resource value and that, as a result, unperceived savings may have a value exceeding perceived time savings if the disutility associated with the alternative activity is also unperceived.

In addition, if minimum blocks of time are required for useful activities, then it follows that schedule rigidities cause some travelers to carry unusable

contingency reserves of time. A small incremental time savings will be valued highly by these travelers if it permits them to free up the contingency reserve for a useful activity. Consequently, the question of how to value small time savings is an empirical issue.

Only a few studies have attempted to investigate empirically the value of time as a function of the amount of time saved and none has considered the value of time for air travelers. Of these, two companion studies by Thomas and Thompson[24] present estimates of the value of small time savings, but serious deficiencies in these studies have been noted in the literature.[25] In brief, reliable estimates of the value of small time savings are unavailable. Other studies have been conducted by Heggie[26] and Henscher.[27] Heggie describes his study as "diagnostic" and does not report estimates of the value of small time savings. Henscher[28] stresses that his study does not address the issue of small time savings and later[29] concedes that the estimates reported in his 1976 study are unreliable because of measurement and statistical problems.

Apart from this consideration, there is another important reason for not treating small time savings differently when evaluating investments or policies affecting a transportation system. Single projects cannot be considered in isolation of a stream of projects which cumulatively save time. If single projects, each saving only small amounts of time, were evaluated under a role which assigns low per unit values to small time savings, underinvestment in the system could occur. This follows because the cumulative benefits of several projects would exceed the sum of the estimated benefits for each project evaluated in isolation. This point has been recognized in the AASHTO Manual,[30] by Yucel,[31] and by Bruzelius.[32]

In summary, the available empirical research supports segmenting the value of time saved by trip purpose and by the earnings rate. Segmentation by other traveler and trip characteristics is not feasible.

D. Summary and Recommendations

Because speed is a principal advantage of air travel relative to alternative modes, the value of time saved to air travelers can be significant in the economic evaluation of FAA investment in regulatory programs affecting time spent in air travel.

A traveler's willingness-to-pay for a reduction in the minimum travel time requirement is the theoretically correct measure of the value of time saved for use in evaluating investment and regulatory programs which affect air travel time. Three recent empirical studies report estimates of the value of air travel time saved that are consistent with this definition. Unfortunately, the range of reported estimates is relatively wide, especially for nonbusiness travel. The range of results reported in these studies suggest that the valuation of travel time saved is still a relatively uncertain exercise. Hopefully, future research will reduce the range of uncertainty.

It is recommended that the hourly earnings rate of the typical business traveler be maintained as a norm or standard value of time saved in air travel for business trips, at least until new evidence suggests that a different basis is warranted. This recommended value approximates the median of the range reported in

recent empirical studies by Pickrell,[33] Morrison and Winston[34] and Grayson.[35] It is also consistent with the earlier findings of Gronau[36] and DeVany.[37]

A standard of 1.5 times the wage rate is recommended as the value of travel time saved for nonbusiness air travel. This standard, which closely corresponds to the Morrison and Winston estimate of 1.49 times the wage rate, is considerably higher than the estimate reported by Pickrell (.21 times the wage rate) and somewhat less than the estimate reported by Grayson (2.14 times the wage rate). The Morrison and Winston nonbusiness trip model is somewhat more sophisticated than the models estimated in other recent studies of U.S. air travelers. In addition, Morrison and Winston employed a larger sample.

1. Recommended Values for Time Saved by User Group

Because of differences in wage rates and trip purposes, the value of time saved will vary across different traffic classes for user groups. Recommended values of travel times for different user groups are presented in Table 2. These estimates have been derived by multiplying the recommended ratios of the value of travel time to the wage rate by estimates of the average wage rates for passengers in the various user groups.

In particular, the recommended values for business trips are equal to estimates of the average wage rates for each of the separate user groups. The recommended values for nonbusiness trips were obtained by multiplying estimates of the average wage rates of nonbusiness travelers in each of the user groups by a factor of 1.5.[38] The final column of Table 2 presents recommended values, by user group, for all trip purposes combined. These values are weighted averages of the values of time saved for business and nonbusiness trips.[39]

The values reported in the first two columns of Table 2 are distinguished both by user groups and by trip purpose. These values are recommended for use when specific user groups and trip purposes that will be affected by an investment or a policy can be identified. If affected user groups can be identified but trip purpose cannot, the weighted average values (for all trip purposes) reported in the final column of Table 2 are recommended. Overall averages are weighted by total person-trips.

Table 2

RECOMMENDED VALUES OF TRAVEL TIME SAVED
BY USER GROUP AND TRIP PURPOSE
(Dollars Per Hour, May 1987 Dollars[42])

User Group	Business Trips	% of all Business Trips	Nonbus. Trips[a]	% of all Nonbus. Trips	Average for all Trips[b]	% of all Trips
Air Carrier						
Domestic Pass.	$25.00	70.8%	$26.97	78.5%	$26.20	75.4%
Int'l Pass.	37.22	1.1%	55.83	7.7%	$50.34	4.8%
Commuter	25.00	4.8%	26.97	5.3%	$26.20	5.1%
GA Piston	38.00	11.8%	57.00	8.4%	$47.52	9.8%
GA Turbine	140.47	7.6%	210.71	0.03%	$140.96	3.2%
Rotorcraft	75.00	2.4%	112.50	0.1%	$78.34	[illegible].1%
Air Taxi[c]	52.65	1.5%	0.00[d]	0.0%	$52.65	[illegible].6%
Government	25.00	0.0%	0.00[d]	0.0%	$25.00	0.0%[e]
Military	20.00	0.0%	0.00[d]	0.0%	$20.00	0.0%[e]
Weighted Average:	$37.06	100.0%	$31.86	100.0%	$33.85	100.0%

a Value of time for nonbusiness trips equals 1.5 x average wage rate of nonbusiness travelers.

b Weighted average by user group. Percent of all trips by user group (in the order they are listed) for business purposes are: 39.1%, 29.5%, 39.1%, 49.9%, 99.3%, 91.1%, 100%, 100%, 100%.[41]

c Fixed-wing passenger trips.

d It is assumed that no nonbusiness trips are taken in this user group.

e Insufficient data; it is assumed trips make up less than .1% of all trips.

2. Recommended Values for Time Saved by Trip Purpose

In order to employ the recommended values of travel time by user group presented in Table 2, it must be possible to identify specific user groups that will be affected by programs affecting air travel time. In some situations, this is not feasible. If this is the case, average values across all user groups are recommended. Recommended average values of time saved in air travel are reported as weighted averages in the last line of Table 2 for business, nonbusiness, and total trips, respectively.

The recommended value of time saved for business trips, averaged across all user groups, is $37.06 per hour (in May 1987 dollars before rounding convention). Similarly, the recommended value for non-business trips, again averaged across all user groups, is $31.86 per hour (in May 1987 dollars before rounding convention). This recommended value differs from that for business trips because of differences in wage rates, differences in the percent of total trips taken by different user groups and because a ratio of 1.5 instead of 1.0 times the wage rate was employed.

Finally, it may not be possible in some situations to identify the type of traveler, business or nonbusiness, or the specific user groups that may be affected by a program. If this is the case, an average value for both user groups and trip purposes is recommended. The recommended value reported in Table 2 is $33.85 per hour (in May 1987 dollars before rounding convention). This value, which is approximately 1.28 times the typical traveler's wage rate, is a weighted average of the values for both user groups and trip purposes.

All recommended values in this section are stated in 1987 dollars. Between interim revisions of this report, it is recommended that the value of time derived in this section be adjusted to future year dollars by the methodology outlined in Section 9.

SECTION 2: VALUE OF A STATISTICAL LIFE

A. Introduction

Placing a value on human life is one of the most troubling questions faced by economists and cost-benefit analysts. Some question the propriety of even raising the issue. Indeed, when one is presented with the opportunity to save a specific life, society seems willing to expend considerable resources. For example, if there is an opportunity to save the life of a person trapped in a mine disaster, typically a community effort is made to save that life, including importantly the volunteering of labor and other resources. During the process, no one stands by and makes a specific accounting of the costs incurred in the rescue operation.

But the opportunities to save lives are not always so immediate. The relevant question for a regulator is how to save lives in the future, lives that could otherwise be lost if government action were not undertaken. When faced with this question, the government cannot predict when or even if (with absolute certainty) a life-threatening situation will occur. Instead, the government is faced with a probablistic circumstance; there may be a statistical probability that a certain number of lives would be lost unless a certain government action is taken. In short, the government is interested in saving "statistical lives."

Seen in this light, the FAA, like other public safety-related agencies, makes decisions about rules, procedures and technologies which have safety implications. The economic principles of these decisions differ little from other public sector decisionmaking. The fundamental test of efficiency involves the familiar comparison of benefits and costs. The FAA must trade-off the marginal benefits of safety improvements against the marginal cost of realizing them. As with all other decision-making, the appropriate investment decision would call for selecting that level of safety investment at which the marginal benefits equal the marginal costs. To select any other level of investment would be inappropriate. For example, if the marginal benefits of potential projects exceed the marginal costs, it would be socially rational for the FAA to invest in additional safety enhancements whose benefits would exceed their costs. Conversely, if the FAA invested in projects where marginal costs exceed marginal benefits, then that level of investment would not maximize the use of available social resources since the additional benefits of the last units of investment would be exceeded by their costs.

This decision-making process is no different from those predicted for consumers, private investors, or for other government activities. The great difficulty with making decisions concerning safety improvements is that safety itself is not a commodity traded in markets. Therefore, it is difficult to know what the benefits are since there are no prices on which to base a value. Aside from this measurement, government must also consider whether there are benefits and costs which matter to society but are less important to an individual. This topic is addressed immediately below.

B. Private and Social Values of a Statistical Life

In the cost-benefit context, the value of a statistical life is a benefit. It represents the costs avoided by a private individual and society of preventing the loss of life. Private individuals may be interested only in those costs which they can avoid, while society would be interested in the net costs avoided by both individuals and other members of society. Since it is a public agency with a safety mission, the FAA is interested in developing an estimate of the social value of a statistical life.

To make the distinction between private and social values of a statistical life more definite, it is useful to identify the elements in each. The following discussion is not meant to exhaust all of the potential elements of private and social values. Depending on the valuation methods used, certain elements could be classified in either the private or social category.

1. Private Value of a Statistical Life

An individual is interested in avoiding the costs he or she would incur as a result of the loss of life. Obviously, the most important element of this is the value of being alive, which would include losses to the (statistical) person affected, the immediate family, and close friends and relatives and others directly affected by the premature death. There are alternative ways for placing a value on this private loss which are discussed below. The key point is that the costs of premature death are incurred privately; the private value of a statistical life excludes costs incurred by parties not directly "related" to the statistical individual.

2. Social Value of a Statistical Life

Society's standpoint is different from the individual's in that it must include the net cost to society due to premature loss of life. This would include the individual's losses, as well as the additional costs to other parties in society that result from the death. For example, in the event of death, society will lose that portion of an individual's income produced but not consumed by the individual. Moreover, there may be medical, emergency, third-party property damage, legal and other costs associated with a fatal aviation accident. These costs could be avoided if the accident were avoided, but they are of little interest to the individual affected who does not incur them directly.

As was noted previously, there are alternative ways of estimating both private and social benefits. These are discussed in turn below, followed by the development of a "consensus" set of values for aviation fatalities.

C. Three General Methods for Estimating the Private Value of a Statistical Life

There are three general methods for estimating private values of a statistical life: the human capital approach, jury awards, and the willingness-to-pay approach. While these methods include the valuation of both private and social values of life, to varying degrees, it is useful to consider them together under the rubric of private values.

Conceptually, the three approaches are relatively straight-forward, but there are a number of nuances that need to be considered. The human capital approach values life as the discounted stream of foregone earnings. If a premature death occurs, one way to identify the loss to the individual (and to society) is to evaluate the reduction in income which occurs as a consequence. The jury awards approach is one which takes values of wrongful death awards from legal decisions and assigns them as the appropriate values for the loss of statistical lives. Juries are free to take into account a number of factors, including not only the value of the life lost, but also punitive damages, and the direct expenses incurred by all parties interested in the case. The willingness-to-pay approach is founded more directly on economic theory. Essentially it says that the government should invest in safety advancements according to what individuals are willing to pay for them. It is closely tied to cost-benefit analysis where the government makes a decision based on examining the marginal benefits and marginal costs of the safety enhancement.

The nuances of these approaches and their applicability to the valuation of statistical lives are discussed in turn below.

1. Human Capital Approach

Regardless of the method eventually selected to value human life, it is obvious that premature death does have the effect of lessening both the production and consumption of goods and services. This fact is the underlying rationale for valuing statistical lives based upon lost future income, or "human capital." The value of that capital is defined as the discounted present value of the stream of expected earnings in the future. In other words, it is the amount of money that an individual would be willing to accept today in exchange for the right to the stream of income between now and either retirement or death.

The logic of the human capital approach is straightforward and does have an economic interpretation. If any productive asset is prematurely destroyed, society loses the value of whatever output it would have produced in its remaining productive years. Under this interpretation, this is true whether the asset is a machine or a human being.

2. Court Awards Approach

Juries are often asked to evaluate the damages to heirs and relatives attributable to wrongful deaths. In such proceedings, it must be established that the defendant has in some way, either deliberately or through negligence, caused the death of a specific individual. Once this is established, the jury is asked to assess the damages to the plaintiff caused by wrongful death.

This approach has an intuitive appeal. Actual payments for wrongful deaths are made every day in the court system. With so many awards being made, it is tempting to conclude that by collecting information on the awards made, it would be possible to develop an estimate of the distribution of life-values based upon the age and other characteristics of the deceased. This kind of distribution could then be applied to the kinds of accidental deaths that an agency such as the FAA would be seeking to prevent.

Typically, court awards are based, at least in part, on the human capital approach. The jury is presented with information on the deceased's income-earning prospects over his or her expected remaining lifetime. To the extent that the decisions are based upon expected foregone earnings, the economic interpretation is the same as that provided for the human-capital approach. However, it should be noted that the jury is free to take into account the costs to related parties who have standing in the case, as well as to assign punitive damages. Since what is included in the damages varies from case to case, use of court award statistics would require information on how much the jury awarded for the loss of life, for any expenses incurred by the public sector, for the bereavement of the family or for direct consequences on related individuals, etc. If such information were available, it would then be possible to sort out the private and social costs.

3. Willingness-to-Pay Approach

The willingness-to-pay approach is closely allied with an economist's concept of cost-benefit analysis. The idea is that the individual is best able to assess the private value of a safety enhancement that affects an activity in which he or she is engaged. As an example, given the right set of information, it should be possible to develop an estimate of what an individual would be willing to pay to have a new ILS system installed at an airport where he or she flies. The assessment would be made based on how the individual valued the decreased risk that would result from the installation of the ILS. If the value of the risk reduction summed over all the individuals who would benefit from the installation exceeded the cost of the safety enhancement, then it would make sense for the government to put it into place.

One of the attractive features of the willingness-to-pay approach is that it is based upon consumer welfare theory. Under this theory, individuals make decisions in life in order to maximize their welfare (well-being) with the income available to them. This simply means that a person seeks to do

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Under the human capital approach, there is another problem which makes valuation of statistical lives problematic in the context of regulatory decision-making. All of the benefits in the human capital approach relate directly to the present value of human productivity. While it is perfectly rational to measure human productivity in order to make investment decisions in industry or government to improve overall productivity, it is troublesome in many circumstances to apply this same measure as a value of statistical lives. For example, the present value of expected future income streams of both the very old and the very young is very small in the human capital formulation. The very old no longer work and the human capital approach may actually show negative human capital values because expected transfers may exceed private income. If a retired person's only source of income was social security, then the expected value of earnings would be zero but since the government would continue to have an obligation to pay social security benefits, one could conclude that the social value of life is negative. This result is so perverse as to cause us to question the appropriateness of the human capital approach to the issue at hand. For a very young person, human capital values are also very low because future income streams are so heavily discounted. Relying on the human capital approach therefore could cause us to under-invest in safety enhancements for the benefit of both the very young and very old.

One way to see the problem inherent in the human capital approach is to respecify the concept in terms of consumer welfare theory postulated for the willingness-to-pay approach. Under the human capital approach, a person would gain welfare only from consumer goods and services which in turn could only be purchased with income. In other words, a person would only be better off if he or she earned more money which would allow them to consume more goods and services. All other activities in life would be valueless. Obviously, such a formulation ignores the fact that there is utility in merely being alive. At some point, the additional income may be far less valuable to an individual than other activities.

Because the shortcomings of human capital were recognized early on, many practitioners incorporated so-called "soft variables" into their human capital analyses. They attempted to estimate the cost of bereavement to family members and friends, losses to the community, and the value of other consequences related directly to premature death. Of course, the very subjectivity of these consequences makes estimating a value for them very difficult.

The willingness-to-pay approach also is the only approach which has a direct link to the cost-benefit analysis that a decision-maker necessarily has to undertake in order to allocate scarce resources. In fact, consumer welfare theory is similar to cost-benefit analysis on an individual level. This close linkage between the government and individual decision-making process is the decisive factor in selecting the willingness-to-pay approach as the appropriate method for valuing statistical lives.

There are a number of issues associated with estimating willingness-to-pay values. Most of them have to do with the application of the concept in studies of actual markets. Before turning to that issue, it is appropriate

to briefly discuss the remaining variables that need to be estimated in order to develop social values of statistical lives.

E. Social Values of Statistical Lives Based on the Willingness-to-Pay Consent[42]

The willingness-to-pay approach does an excellent job of incorporating most of the private consequences of premature death. Specifically, these values reflect an individual's own willingness to accept physical risks and therefore are directly related to the value he or she places on life. There are some private consequences which may or may not be captured by the willingness-to-pay approach, however. Paramount among these is the income produced by an individual and consumed by dependents which would be denied to dependents in the event of the death of the individual. The extent to which potential loss of this income is reflected in willingness-to-pay estimates is a function of the individual's preferences (utility function) and the availability and/or terms upon which potential financial losses in the event of death can be pooled with others through such means as life insurance. If an individual does not wish to provide an income for dependents in the event of death, the willingness-to-pay estimates will not reflect such income. If the well-being of dependents in the event of the individual's death does enter the individual's preferences, the availability and/or terms on which life insurance can be obtained will determine the extent to which the willingness-to-pay estimates reflect the potential loss of this income.

As examples, if life insurance is not available, the rational individual will probably be willing to pay more for risk reduction because dependents can only be provided for by increasing the individual's probability of remaining alive. Thus, the willingness-to-pay estimates will reflect the individual's valuation of potential lost income to dependents in the event of the individual's death. If life insurance is available, willingness-to-pay estimates will not reflect potential income loss to dependents if the insurance premium does not vary with the level of risk to which the individual is subjected. (Why pay more for risk reduction than you otherwise would when your dependents well being can be provided for without incurring additional insurance costs?) If insurance is available and priced based on risks to which the individual is exposed, the willingness-to-pay estimates will reflect lost dependent income because the individual will be willing to accept increased exposure to risk only if the risk premium offered includes an amount to insure the additional risk.

A related situation occurs when an individual is a key person in a business and premature death could cause substantial damage to the well-being of co-workers or stockholders. Because the individual may or may not include such consequences in his or her private decisionmaking, willingness-to-pay estimates may not reflect the losses to co-workers or stockholders should the person die. Even if the company or the affected parties should insure the life of the individual, this would not necessarily be reflected in the willingness-to-pay of the individual.

The extent and relative occurrence of these and related situations in the populations studied in the various willingness-to-pay studies cited below is unknown. In the absence of such information, this study makes no adjustment to the willingness-to-pay estimates to reflect income produced by an individual but which is consumed or which accrues to other private parties and which would be lost in the event of the individual's death. Thus, the estimates may understate the true social value of life.

Aside from the private consequences of premature death discussed above, what are the additional social consequences? There are two categories. A person's willingness-to-pay is based in part on income. That income would include after-tax earnings, investment income, and net expected future transfers from government programs such as social security or elsewhere. The individual's view of the income available to him is not the same as society's view of the income that would be lost due to premature death. Society would lose the value of expected future taxes that the individual would have paid. Even though the individual does not take the value of these taxes into account in his own decision making, society does lose them and therefore they are appropriately included in the social costs of premature death.

The second category involves other direct costs associated with premature death. Included in this category are medical expenses, legal and court costs, costs of emergency efforts, and public and insurance administration costs. All of these expenses can be avoided, or at least deferred, for many years, if premature death can be avoided. They are therefore appropriately added to a socially rational valuation of a statistical life.[43]

Fortunately, all of these values needed to develop estimates of socially rational investments to avoid premature deaths are directly observable. However, because safety is not traded in actual markets, estimating private willingness-to-pay for safety improvements is more difficult.

F. Estimating Private Willingness-to-Pay for Safety Enhancements

Because safety is not directly traded in markets, it is necessary to develop methodologies for estimating an individual's willingness-to-pay for it. There have been essentially two methods used in the past: the survey approach and the econometric studies of labor and product markets.

1. Survey Approach

Under the survey approach, an individual is asked a series of questions designed to help him develop a value for what he would be willing-to-pay to avoid a postulated risk. For example, a person might be asked how much he or she would be willing-to-pay to reduce his or her chances of a heart attack from one in five hundred to one in one thousand.

There are two obvious problems with this approach which have to be considered. First, it is difficult for people to relate to very small changes in risks. Some risks, such as the probability of an aviation

accident, are so small, e.g. one for 100,000 operations, that it is difficult for an individual to distinguish between even large differences in risk, for example, the doubling or tripling of the probability of an accident. Second, there are almost always wide differences in people's responses to such surveys. Unless there is a meaningful central tendency in the results, they may not be applicable to any particular situation. Third, there is difficulty in interpreting cases where people assign a zero value to safety improvements. Unless these represent rational responses, the distribution and therefore the applicability of the results of the surveys may be in question.

2. Labor Market Studies

A second class of willingness-to-pay studies examines the wage premium earned by workers to accept different levels of risks on the job. While there have been several survey studies of this type, most recent studies apply econometric techniques to evaluate the marginal willingness of workers to accept different levels of risk in exchange for wage premiums. The models seek to explain the variation in wages based upon the characteristics of the worker (education, experience, age), the requirements of the job (skill levels, educational requirements, supervisory experience) as well as other factors including the relative scarcity of the particular type of labor in question. Included in the models are measures of fatality risk. If the models are correctly specified, then a significant coefficient for the accident risk variable is a crude measure of willingness to accept risk. More sophisticated measures of willingness-to-pay can also be developed from these models.

There are two important problems that are peculiar to the labor market studies. The first pertains to the mobility of labor in actual labor markets. The assumption which underlies these studies is that labor markets are competitive, and that workers have mobility between jobs. A worker who is unwilling to accept risk in exchange for "a wage premium" could instead change jobs and receive a slightly smaller wage in exchange for a safer working environment. Because of indivisibilities, a worker may not be able to trade off safety in incremental amounts. More troubling is the fact that he may not be able to change jobs at all because of inefficiencies in the market.

The second problem pertains to the measure of wage rates used in the studies. An individual's willingness-to-pay is presumably based upon after-tax income. Therefore, the dependent variable in the wage equations in the studies should be after-tax income. An examination of the literature shows this not to be the case for most studies. Results of the labor market studies presented below have been adjusted to reflect the fact that willingness-to-pay should be based on after-tax income.[44]

3. Product Studies

A third class of studies directly evaluates the relative risks of a class of products. Willingness-to-pay to avoid risks can be measured in two ways in such studies. For a homogeneous class of products which exhibit different safety records, the price premiums paid for safer products after adjusting for all other characteristics provide measures of willingness-to-pay. Alternatively, the willingness of individuals to use safety-enhancing products, e.g. seat belts, can also be studied. By correlating characteristics with product use, it is possible to evaluate the willingness to accept the risk or to pay to avoid it.

All of these studies are performed using econometric techniques. One key question about such studies concerns the identification of the demand for the product in question. Many of the product-specific studies are single equation models with the price of the product as the dependent variable. Simplifying assumptions have to be made in order for a researcher to identify a locus of equilibrium points as a demand curve. Other studies separately specify demand and supply curves for the product and are therefore able to avoid this "identification problem."

Product studies, like labor market studies, presume that consumers (or workers) know what is good for them. If some risks are hidden from the consumer, then presumably they will not be reflected in market prices and these studies will underestimate willingness-to-pay. In such cases, however, it is the government's duty to make the information available in order to correct a market failure. These studies implicitly assume that government identifies hidden risks as they become known and makes them public.

G. Estimates of the Value of Statistical Life for FAA

Developing appropriate estimates for FAA decision-making requires the collection of information on both the private and social benefits of safety enhancements. The various measures which make up these estimates are discussed in turn below.

1. Estimates of Private Willingness-to-Pay

Table 3 reports the results of several willingness-to-pay studies conducted in the 1970's and 1980's. The studies shown in the Table have been evaluated independently in a survey article by Miller[46] and judged to have appropriate risk variables, correct specifications, and statistically significant results.

Table 3 separates the various studies into the three types discussed previously: surveys, labor market studies, and studies of specific products. A quick perusal of the table shows that there is a wide diversity of results. In general, the survey studies evidence higher values of life than either of the other two types. The variance in the studies of specific products is smaller than the variance in values drawn from the labor market studies. On the other hand, there are more labor market studies from which to draw.

Table 3

VALUE OF LIFE ESTIMATES FROM CREDIBLE STUDIES[46]
(after-tax $000, 1985)

Labor Market Studies	Publication Year	Type of Worker	Value
Melinek[47]	1974	Blue Collar	$1,285[a]
Viscusi[48]	1978	Blue Collar	1,345-2,654
Brown[49]	1980	Blue Collar	1,052
Viscusi[50]	1980	Union	2,538
		Non-Union	0
Marin and Psacharopoulos[51]	1982	Blue Collar	1,791[a]
Butler[52]	1983	Blue Collar	820-832[b]
Dillingham & R.Smith[53]	1983	Union	0-3,462
		Non-Union	1,356-2,731
V.Smith[54]	1983	All	1,078-1,940[c]
Dickens[55]	1984	Union	1,634-1,918
		Non-Union	0
V.Smith & Gilbert[56]	1984	All	1,016-1,893[c]
Dillingham[57]	1985	Blue Collar	971-1,420[d]
		Blue Collar	1,513-1,937
Gegax, et al.[58]	1985	Union	1,163-1,396
		Non-Union	0
Viscusi[59]	1986	All	1,200-1,500[b]

Consumer Behavior Studies	Publication Year	Subject	Value
Melinek[60]	1974	Use of pedestrian walk	$1,386[e]
Ghosh et al.[61]	1975	Speeding	854[e]
Blomquist[62]	1979	Seatbelt use	939[e]
Dardis[63]	1980	Smoke detectors	260-1,146[f]
Landefeld & Seskin[64]	1982	Life insurance	873
Jondrow et al.[65]	1983	Speeding	1,061[g]
Ippolito & Ippolito[66]	1984	Smoking	384-1,240[h]
V. Smith & Gilbert[67]	1984	Jobs in unpolluted SMSAs	1,329-2,462[i]
Winston & Mannering[68]	1984	Auto safety features	1,239
Survey Studies			
Landefeld[69]	1979	Cancer	2,394
Gegax[70]	1984	Labor market	2,017[j]
Jones-Lee et al.[71]	1985	Highway safety	2,559
		Average $000, 1985:	1,482.962[k]
		Adjustment to 1987 Dollars:	1.0635[l]
		Average $000, 1987:	1,577.129

Table 3 (Continued)

VALUE OF LIFE ESTIMATES FROM CREDIBLE STUDIES

Footnotes

[a] British study. Melinek adjusted to after-tax dollars, and his marginal tax rate (33 percent) was used to adjust Marin and Pasacharopoulos's value.
[b] Regression was performed in after-tax dollars.
[c] Adjusted using a factor of 25-45 percent to separate fatal and nonfatal risks based on Dillingham (1983), Viscusi (1978), Butler (1983) (all cited above), Leigh and Folsom,[72] and Olson.[73]
[d] Corrects Dillingham (1979, cited above).
[e] Reanalyzed by author using a value of time equal to 60% of the wage rate per passenger and 120% of the wage rate per vehicle.
[f] Recalculation by Miller using net present values instead of annualized costs. Based on a 5 percent discount rate. Values are range across years.
[g] Estimated by Miller based on the equation given in Jondrow et al., the optimal speed limit in the Gallup poll cited in Transportation Research Board,[74] and a value of time equal to 120 percent of the wage rate per vehicle.
[h] Based on a 5 percent discount rate. Values are underestimates due to failure to totally account for the addictive effect of heavy smoking.
[i] Recalculation by author using the family size of 3 assumed in Portney.[75]
[j] Adjusted to after-tax dollars by Miller.
[k] Mean of all values for labor market, consumer behavior, and survey studies excluding zero values and Dillingham and R. Smith, 1983, (mid-point of 0-3,462 range cannot be determined if zero values are rejected).
[l] Using GNP implicit price deflator for total personal consumption expenditures.

2. Adjustments Needed to Derive Social Benefits

There are two categories of adjustments in addition to the private values of a statistical life needed to reach estimates of social values. They are discussed in turn below.

Foregone Taxes: Foregone taxes are defined as the estimated discounted present value of expected future earnings multiplied by the applicable state, local and federal tax rates. The result is the lost tax revenues that the government will not collect as a result of premature death. Table 4 presents the derivation of foregone taxes in 1987 dollars. It is assumed that a person's earnings would grow at the real rate of one percent per year from the date of the accident to retirement age of 65. The present value of the annual amounts are derived using a discount rate of 10 percent. The result of the present value calculation is then multiplied by the estimated effective tax rates to derive the present value of foregone taxes in 1987 dollars.

Other Direct Costs: There are a host of other potential direct costs occasioned by premature death, including medical and emergency costs, legal and court costs (the cost of carrying out court proceedings, not the cost of settlements), and costs associated with administration of public assistance insurance.[76] These other values are adopted from a study by the National Highway Traffic Safety Administration[77] and sum to a total of $33,093 in 1987 dollars. All of these expense estimates are based upon per-fatality costs in automobile accidents and are used here because of the limitations of similar data for aviation accidents.

H. Consensus Results

Table 5 presents a summary of the "consensus" results of the socially rational level of investment to prevent the loss of a statistical life applicable to FAA programs. Both the private and additional increments necessary to derive social values are summarized in the table in 1987 dollars for all user groups. A weighted average based on 1986 person trips totaling $1,740,000 (using the rounding convention and updating methodology presented in Section 9) is derived.

Table 4

ESTIMATES OF FOREGONE TAXES BY USER GROUP
(1987 dollars)

User Group	Wage Rate[78]	Annual Salary[a]	Mean Age[79]	PV of Lifetime Earnings[b]	Effective Tax Rate[80]	Foregone Taxes
Air Carrier						
Domestic Pass.	$20.72	$41,440	39.3	$326,861	28.0%	$ 91,522
Int'l Pass.	37.22	74,440	36.6	847,359	28.0%	237,261
Commuter	20.72	41,440	39.3	326,861	28.0%	91,522
GA Piston	38.00	76,000	45.1	772,049	28.0%	216,173
GA Turbine	140.47	280,940	45.1	2,558,924	28.0%	716,499
Rotorcraft	75.00	150,000	39.3	1,235,828	28.0%	346,032
Air Taxi	52.65	105,300	39.3	830,561	28.0%	232,557
Government	25.00	50,000	39.3	394,379	28.0%	110,426
Military	20.00	40,000	30.0	419,821	28.0%	117,550

[a] Assuming a 2000 hour work year.
[b] Earnings through age 65. Actual age distributions by user group were used in obtaining discounted lifetime income streams.

Table 5

VALUE OF A STATISTICAL LIFE, SUMMARY OF THE "CONSENSUS" RESULTS
(1987 dollars)

User Group	Individual Willingness-to-Pay	Foregone Taxes	Other Social Costs	Percent of all Aircraft Trips[81]
Air Carrier				
Domestic Pass.	$1,577,129	$ 91,522	$33,093	75.4%
Int'l Pass.	$1,577,129	$237,261	$33,093	4.8%
Commuter	$1,577,129	$ 91,522	$33,093	5.1%
GA Piston	$1,577,129	$216,173	$33,093	9.8%
GA Turbine	$1,577,129	$716,499	$33,093	3.2%
Rotorcraft	$1,577,129	$346,032	$33,093	1.1%
Air Taxi	$1,577,129	$232,557	$33,093	0.6%
Government	$1,577,129	$110,426	$33,093	0.0%[a]
Military	$1,577,129	$117,550	$33,093	0.0%[a]
Weighted Average:	$1,577,129	$134,378	$33,093	

Average Socially Rational Valuation, 1987: $1,744,600 or $1,740,000[b]

[a] Insufficient data, probably .1% or less of all trips.
[b] Rounded to nearest $10,000 based on the rounding convention recommended in Section 9.

SECTION 3: UNIT COSTS OF STATISTICAL AVIATION INJURIES

A. Introduction

The unit cost of a statistical injury and the unit cost of a statistical life are companion "critical values" used by the FAA for the evaluation of its investment and regulatory programs. Unlike placing a value on the life of a human being, estimating the cost of aviation injuries to society is less controversial. However, there is some controversy in the case of injuries that involve substantial amounts of pain and suffering or permanent impairment, such as severe burns, head or spinal cord injuries.

The primary issue with the estimation of the costs of statistical injuries, especially those costs involving pain and suffering, is the choice of appropriate methodology. The approaches discussed in the preceding section for the value of a statistical life -- court awards, human capital and willingness-to-pay -- are the same methodologies, with appropriate modifications, discussed here for estimating the costs of injuries. However, additional and sometimes difficult to find information is required for components of the cost of a statistical injury that is not required for the estimation of the value of a statistical life. For example, while little or no medical service is required for an accident victim who dies at the scene of the accident, or shortly afterwards, an injury victim may require hospitalization, surgery, medication or rehabilitation after the accident.

This section reviews the three approaches generally considered to have usefulness in estimating the costs of statistical injuries: court awards, human capital and willingness-to-pay. Estimates using the last two approaches are obtained for nine aviation user groups and five levels of injury severity. Special estimates are also provided for particular injuries resulting in lifetime impairment and/or lifetime medical and support costs.

The same user groups as defined in Sections 1 and 2 will be considered: air carrier domestic and international passenger; commuter; traditional general aviation fixed wing piston engine; traditional general aviation fixed wing turbine; all rotorcraft; air taxi (fixed wing piston and turbine); government (all aircraft types); and military (all aircraft types).

Injury levels and the resulting costs of injuries are disaggregated using the Abbreviated Injury Scale (AIS). This injury classification system fulfills FAA's need to expand the classification of injuries beyond the current injury levels of "minor" and "serious." The AIS system has also been used in recent applied work by the National Highway Traffic Safety Administration,[82] Miller et al. (1984),[83] and Miller et al. (1988).[84]

The AIS classifies nonfatal injuries into five categories depending on the short-term severity of the injury. A minor AIS injury (coded 1) corresponds to a "minor" NTSB injury while AIS moderate, serious, severe and critical

injuries (coded 2 through 5) correspond to a "serious" NTSB injury (and "minor" and "serious" injuries in prior editions of FAA Economic Values...). Injury values are also provided for injuries the NTSB classifies as "maximum." Maximum injuries are not immediately fatal, but do result in the death of the injured individual within one year of an accident in virtually 100% of the cases which are tracked for that length of time.

The five nonfatal AIS injury categories are based primarily upon the threat to life posed by an injury as determined by physicians. Other factors that are used to rate injuries include: permanent impairment, treatment period, and incidence. While the AIS was developed for use in automotive accidents, it is appropriate for use in many types of situations since the scale is based on the threat to the life of an accident victim rather than the type of accident in which the victim was injured. Table 6 gives an overview of the classification of different injuries by AIS level and their threat to life.

Table 6

Selected Sample of Injuries by the Abbreviated Injury Scale (AIS)

AIS Code	Injury Severity Level	Selected Injuries
1	Minor	Superficial abrasion or laceration of skin; digit sprain; first-degree burn; head trauma with headache or dizziness (no other neurological signs).
2	Moderate	Major abrasion or laceration of skin; cerebral concussion (unconscious less than 15 minutes); finger or toe crush/amputation; closed pelvic fracture with or without dislocation.
3	Serious	Major nerve laceration; multiple rib fracture (but without flail chest); abdominal organ contusion; hand, foot, or arm crush/amputation.
4	Severe	Spleen rupture; leg crush; chest-wall perforation; cerebral concussion with other neurological signs (unconscious less than 24 hours).
5	Critical	Spinal cord injury (with cord transection); extensive second- or third-degree burns; cerebral concussion with severe neurological signs (unconscious more than 24 hours).

The complete AIS coding system is presented in the 1988 NASS Injury Coding Manual.[85] This publication should be used as the final source of information when classifying injuries prior to determining their economic values.

There is one rather important caveat in the use of this system. Since the five AIS injury categories are based on the threat that injuries pose to life, some expansion of these categories is needed to provide a system useful for estimating the full economic costs of injuries. As Miller *et al.*[86] report:

> Unfortunately, the purpose of the AIS scale is to differentiate injuries by the threat they pose to life, not the cost, disability, or trauma they involve. For example:
>
> o Loss of teeth is an AIS-1 injury that can involve substantial costs and lifetime pain and suffering.
> o Loss of a hand or foot is an AIS-3 injury involving partial permanent disability.
> o Timely, successful surgery often allows complete and rapid recovery from potentially fatal internal injuries coded in AIS categories 3 through 5.

This study will in part compensate for this problem by making special estimates for certain severe AIS 4 and 5 injuries and providing willingness-to-pay estimates which incorporate the cost of reduced utility of living due to an injury. Using NHTSA and Miller *et al.*[87] estimates as a guide, estimates will be made for the value of AIS 4 and AIS 5 spinal cord, head and burn injuries by degree of severity. The average injury cost estimates for AIS levels 4 and 5 will include the average prevalence of these special injuries when compared to other level 4 and 5 injuries.

B. Court Awards Approach

The court awards or judicial process approach entails examining jury awards and settlements involving litigation of aviation injuries. The components of awards and settlements include some or all of the following: lost earnings or potential earnings, present or future medical or related costs and pain and suffering. Court awards may also include a portion for costs borne by relatives in the form of pain and suffering or for loss of services.

A number of publications provide the legal community with selected case information on injury litigation, including aviation cases. Examples of these publications are presented and discussed in Section 11.[88] Because primary research on jury awards was not possible for this publication, these sources would need to be used as secondary sources for a statistical estimate of the costs of aviation injuries. These sources generally present illustrative rather than randomly selected cases. Cases can be selected because they represent extreme settlements, either high or low, or because they demonstrate a particular legal principle. As such, these secondary

sources do not provide a good basis for deriving statistical court award values.

There are also theoretical disadvantages to using the court awards approach in estimating the value of aviation related injuries. This approach is not directly related to either consumer or social welfare theory. Because the award only represents a transfer of wealth from the negligent party to the injured party, there is generally no compelling reason for that award to represent the true economic cost of an injury. It is the jury or the court system in general that determines the dollar amount that the accident victim is to receive rather than the injured party himself. Awards result only from accidents involving claims of negligence. Awards may vary according to the sympathy of the court, the skill and ability of the attorneys for the plaintiff or defense or the defendant's ability to pay. Awards may reflect a penalty for contributory negligence on the part of the accident victim.

For these reasons, the court awards approach is not likely to accurately reflect the true economic costs of a statistical injury. Certain costs to society, such as foregone federal/state income taxes, investigation costs or the court costs themselves, are not generally reflected in the jury awards or settlements. "Token" awards or no award at all can accompany serious injuries if little or no negligence is found.

The court award summary information presented in the 1981 edition of Economic Values...[89] can be updated using a recent study of trends in tort law.[90] Using the increase in personal injury awards (excluding product liability and wrongful death) from the period 1975-79 to 1980-84 as a guide, aviation related injury settlements could have averaged between $5,000 and $7,700 for minor accidents from 1980 to 1984 and between $425,000 and $650,000 for serious accidents. This represents increases in average awards of between 49% and 121% between the two time periods (depending on the jurisdiction considered). It is also interesting to note that these average awards reflect strong growth in million dollar awards. In 1980-84, million dollar awards accounted for 65% of all personal injury dollars awarded in Cook County, Illinois and 47% of all dollars awarded in San Francisco, California. It is likely that this trend in award increases has continued into the 1985-1988 time period.

Because of the many problems with using the court awards approach to value aviation injuries, estimates based on this approach should be considered for comparative purposes only, and not used in evaluative decision making.

C. Human Capital Approach

The human capital approach is the most common method utilized for the estimation of injury costs in the context of cost/benefit decisions. The difficulties that this approach presents in the context of valuing a statistical life (see Section 2) can be less restrictive in obtaining costs of injuries. While the productivity and utility a victim derives from life is completely lost in a fatal accident, the productivity and life utility for a victim of a nonfatal accident is lost only to the extent that the resulting

injuries prevent the victim from pursuing productive labor or fully realizing the utility of living. Injuries may result in the loss of only one day of productivity and realistically little utility, or many years. An injury victim may recover completely from the injury, or, as in the case of severe head or spinal cord injuries in which the victim never fully recovers, the victim's level of productivity and enjoyment of life can be severely reduced.

Consequently, human capital derived costs of injuries have less potential for error when they represent less severe injuries. Recommended costs of injuries presented in this section will use the human capital approach only for AIS Level 1 (Minor) injuries. These estimates are presented in Table 9-A (following Part D, Willingness-to-Pay). All other estimates use the willingness-to-pay approach discussed in Part D. Alternate human capital based estimates for all injury levels are presented for comparative purposes in Alternate Tables 9-B through 9-E and Alternate Tables 10-A through 10-E in Section 10.

Studies done by the NHTSA[91] and Miller et al.[92] are used as models for the human capital approach discussed here. The contribution of the latter study to this approach, and to the willingness-to-pay approach discussed in Part D, is: updated medical costs, weighted prevalence of severe injuries in deriving AIS level 4 and 5 baseline costs, and revised baseline costs for spinal cord, head and burn injuries. All medical, emergency medical, legal, and other administrative costs are based on updates made by Miller et al. to previous NHTSA estimates. NHTSA estimates provide the time path of lost income, medical expenses, and other costs for which time discounting is relevant.

The cost of lost human productivity is the cost element included in human capital estimates of the unit cost of aviation statistical injuries, but absent in willingness-to-pay estimates. As such, only lost productivity will be discussed at this time. Other cost elements are presented in Part D.

Productivity losses are defined as the discounted present value of foregone earnings attributable to a typical aviation user who experiences an aviation related injury. Earnings levels and mean age by user group will be taken from estimates in Sections 1 and 2. Estimates of lost work time are taken from Miller. To maintain consistency with the value of statistical life results, these estimates assume a productive life from age 21 to 65, average productivity increases of one percent per year, average inflation of five percent per year, and a discount rate of six percent.

There is considerable debate in the literature concerning the impact and choice of wage growth and discount rate assumptions in human capital calculations. This debate is summarized in Section 11 using recent work by Carpenter et al.,[93] Jones (and Rejoinder by Schilling),[94] Brown,[95] and Schilling.[96] In response to this issue, lost productivity estimates will be discounted at a rate of six percent.

It should be noted that the discount rate employed here is lower than the 10 percent rate suggested by OMB. The reasons for this difference are

presented in a discussion on appropriate discount rates for public expenditures in Section 11.[97] The NHTSA used a seven percent discount rate in their 1983 estimates, and six percent in 1986, while also using similar productivity and wage-growth assumptions to those used here. Such assumptions produce NHTSA estimates of lost productivity due to automobile injuries readily comparable to the human capital based estimates given in this study.

D. Willingness-To-Pay Approach

The approach described here assumes that the rational level of social investment for the reduction of injuries equals the individual's willingness-to-pay to avoid or reduce injury plus the costs to society which would be avoided by the safety improvement. This result will be called the "socially rational investment". Because it proceeds from consumer welfare theory, the willingness-to-pay approach provides a firm basis for the costing of injuries. The advantages and application of this approach to valuing human life was discussed in Section 2.

The traditional obstacle to the application of this approach to the costing of injuries was the lack of good empirical work demonstrating individual willingness-to-pay to reduce the risk of injury. Death is a binary outcome. The individual's willingness-to-pay to avoid this outcome has been examined in a substantial body of economic literature. However, the continuous range of injury severity has made it impossible to measure directly individual willingness-to-pay to avoid injury or to avoid a particular degree of injury. By default, this problem has made the human capital approach the usual method of choice.

Miller[98] provides an intuitively appealing method of deriving individual willingness-to-pay to avoid injury. The assumption is made that aggregate estimates of individual willingness-to-pay to avoid loss of life can be disaggregated into a yearly value for the utility of living. The NHTSA then estimated the number of "functioning" years lost by different degrees of injury severity. "Functioning" years was defined as years of impairment plus years of life lost due to the life-shortening effect of many serious injuries. These estimates were made originally for automobile accidents. For this study, the NHTSA[99] adjusted their automobile accident based estimates for the difference in age distribution between the motor vehicle injured population and the aircraft injured population using aircraft injury data provided by the FAA. The yearly value of life is applied to the appropriate number of lost functioning years and discounted. This is the approach used here to derive the individual willingness-to-pay component of socially rational investments to avoid injury.

The individual willingness-to-pay value derived in Section 2 is used here to estimate a yearly value for the individual's utility of living. Using a six percent discount rate,[100] and an average remaining life span of 38 years,[101] a value of life of $1,577,129 indicates a yearly utility of life of $103,182 ($1987). This will be the base value used in developing the individual willingness-to-pay component of socially rational investment. In

comparison, Miller uses a yearly life utility value of $120,000 for the average person injured in an automobile ($1986, using a six percent discount rate). As such, the estimate of individual willingness-to-pay used here can be considered as a minimum value.

Table 7 gives Miller's estimates of functioning years and work years lost for average AIS 1 to AIS 5 level highway injuries. Based on an analysis performed for the FAA by NHTSA, Table 7 also presents the number of functional years of life lost to persons injured in aircraft accidents. These estimates combine the effect of life shortening due to an accident and percentage reduction in life utility due to the short and/or long term effects of the accident.

Table 7

Years of Functioning and Work Life Lost Per Injury, by Severity

	Years Lost		
	Functioning		
Injury Severity	Adjusted for Aviation	Motor Vehicle	Work
AIS 1	.013	.013	.005
AIS 2	.17	.2	.03
AIS 3	1.38	1.5	.085
AIS 4	4.56	4.8	2.05
AIS 5	23.93	26.3	5.65

The aviation-adjusted estimates of functioning years lost in Table 7 were used to obtain estimates of the individual willingness-to-pay component of socially rational investment by injury level. The resulting stream of yearly lost life utility was discounted at six percent. The discounting approach used approximates the effect of monthly discounting. For example, values for the first and second years were discounted as follows:

$$\text{Year One Value} = (\text{Base Value})/(1.06^{.5})$$

$$\text{Year Two Value} = (\text{Base Value})/(1.06^{1.5})$$

The willingness of individuals to pay to avoid the loss of the utility of living is only one component of socially rational investment to avoid the cost to society of injuries due to aviation accidents. Other components are discussed below. In those cases in which costs are likely to extend beyond a few weeks after an accident, costs are discounted at a yearly rate of ten percent. This rate represents the OMB-recommended rate for discounting a future stream of costs to society.

Foregone taxes are the tax revenues society loses from an injured person during the time he or she is unable to work. Income levels by user group presented in Section 2 were multiplied by the number of work years lost in Table 7. A total effective tax rate of 28 percent was used to reflect all income-related taxes lost.[102]

Medical costs include all costs from admission to an emergency room to release from the hospital, medicine, doctor and follow-up visits. Costs are adjusted to 1987 dollars using the Consumer Price Index (CPI) for Medical Care and are discounted at the OMB-suggested rate of ten percent. Costs for AIS Level 1, 2 and 3 injuries are discounted for one-half year on the assumption that medical costs could extend beyond a few weeks. For AIS level 4 and 5 injuries, lifelong medical costs are reduced by the estimated reduction in life years due to the injury. Medical costs given for severe and critical spinal, head and burn injuries include long-term medical care, residentiary, vocational rehabilitation, at-home nursing, home modifications, and special appliance purchases when appropriate.

Emergency costs include costs of medical care administered prior to admission to an emergency room, the cost of transporting the accident victim, police and firefighter costs. While these costs were originally estimated for automotive accidents, they are included for the sake of completeness, since corresponding statistical data for aviation accidents are not available. These costs may be thought of as being the minimum emergency costs for aviation accidents. Costs were inflated to 1987 dollars by applying the CPI for Medical Care. Because these costs occur immediately following the accident they are not time discounted. These costs are combined in Tables 9-A to 10-E (but indicated in a footnote) with "medical costs" (above) under the heading "total medical costs."

Legal/court costs include court, attorneys', prosecutor's, and related staff fees. Costs were inflated to 1987 dollars by applying the CPI for All Items. The average time path of these costs is uncertain. The assumption is made that they average one-half year in duration and are discounted accordingly.

Other administrative costs include the costs of administering life and health insurance programs by insurance companies and transfer payment programs by federal, state and local governments. Costs were inflated to 1987 dollars by applying the CPI for All Items. Baseline estimates assume annual cost increases of five percent, and are time discounted by ten percent. These costs are combined with "legal/court costs" in Tables 9-A through 10-E (but legal/court costs are identified in a footnote) under the heading "legal, court, other administrative costs."

Tables 9-A through 9-E present estimates of the socially rational level of investment to avoid aviation injuries by user group and degree of injury severity. Parallel estimates using the human capital approach are presented in Section 10, Alternate Tables 9-B through 9-E. A weighted average socially rational level of investment is obtained in each table using the relative percentage of all aircraft trips made by users in each group. Note that Table 9-A recommends the human capital approach as the basis for AIS Level 1

(Minor) injury estimates and "Productivity Losses" replaces "Individual Willingness-to-Pay" and "Foregone Taxes" in that table only.

A particular advantage of the willingness-to-pay approach is its ability to capture the cost of "fates worse than death." It is difficult to maintain that human capital estimates of lost productivity adequately capture the full human cost of severe head, spinal cord and burn injuries. There is a growing body of literature, documented in Miller,[103] which estimates the total life utility lost due to these severe injuries. Table 8 presents estimates of the percentage of life utility loss based on an average of the findings discussed by Miller. Many of these percentages exceed 100%, because of the effort made by researchers to capture the concept of a "fate worse than death."

Table 8

Percentage Utility Loss Associated with Severe Injuries

	AIS 4		AIS 5	
	Quadriplegia	Paraplegia	Quadriplegia	Paraplegia
Spinal Cord	109%	46%	109%	53%
	Total Disability	Partial	Total Disability	Partial
Head	117%	15%	117%	62%
Burns	138%	138%	138%	138%

Tables 10-A through 10-E present socially rational levels of investment estimates for AIS level 4 and AIS level 5 spinal cord, head and burn injuries. The individual willingness-to-pay component is derived by taking the appropriate percentage utility loss and multiplying it times the individual willingness-to-pay to avoid loss of life estimate by user group from Section 2. No discounting is required because the aggregated value of life estimates are already implicitly discounted. All other cost components are derived as discussed above for other willingness-to-pay estimates. Comparable estimates using the human capital approach are presented in Section 10, Alternate Tables 10-A through 10-E.

Table 9-A

Unit Cost of AIS Level 1 (Minor) Aviation Injuries
($1987)

FAA User Group	Productivity Losses	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[104]
Air Carrier				
Domestic Pass.	$683	$299	$1,140	75.4%
Int'l Pass.	987	299	1,140	4.8%
Commuter	683	299	1,140	5.1%
GA Piston	1,007	299	1,140	9.8%
GA Turbine	3,724	299	1,140	3.2%
Rotorcraft	1,988	299	1,140	1.1%
Air Taxi	1,396	299	1,140	0.6%
Government	683	299	1,140	0.0%[c]
Military	530	299	1,140	0.0%[c]
Weighted Average:	$845	$299	$1,140	

Average Socially Rational Investment, 1987: $2,284 or $2,300

[a] Emergency medical costs, $71 of total for all user groups.
[b] Legal and Court Costs, $301 of total for all user groups.
[c] Insufficient data, probably .1% or less of all trips.

Table 9-B

Unit Cost of AIS Level 2 (Moderate) Aviation Injuries ($1987)

FAA User Group	Individual's Willingness-to-Pay	Foregone Taxes	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
Air Carrier					
Domestic Pass.	17,541	348	1,918	1,884	75.4%
Int'l Pass.	17,541	846	1,918	1,884	4.8%
Commuter	17,541	348	1,918	1,884	5.1%
GA Piston	17,541	798	1,918	1,884	9.8%
GA Turbine	17,541	2,368	1,918	1,884	3.2%
Rotorcraft	17,541	1,316	1,918	1,884	1.1%
Air Taxi	17,541	885	1,918	1,884	0.6%
Government	17,541	420	1,918	1,884	0.0%[d]
Military	17,541	336	1,918	1,884	0.0%[d]
Weighted Average:	$17,541	$495	$1,918	$1,884	

Average Socially Rational Investment, 1987: $21,838 or $22,000

Table 9-C

Unit Cost of AIS Level 3 (Serious) Aviation Injuries ($1987)

FAA User Group	Individual's Willingness-to-Pay	Foregone Taxes	Total Medical Costs[e]	Legal, Court, Other Admin. Costs[f]	Percent of all Aircraft Trips[c]
Air Carrier					
Domestic Pass.	136,802	986	7,871	2,874	75.4%
Int'l Pass.	136,802	2,396	7,871	2,874	4.8%
Commuter	136,802	986	7,871	2,874	5.1%
GA Piston	136,802	2,262	7,871	2,874	9.8%
GA Turbine	136,802	6,710	7,871	2,874	3.2%
Rotorcraft	136,802	3,729	7,871	2,874	1.1%
Air Taxi	136,802	2,506	7,871	2,874	0.6%
Government	136,802	1,190	7,871	2,874	0.0%[d]
Military	136,802	952	7,871	2,874	0.0%[d]
Weighted Average:	$136,802	$1,401	$7,871	$2,874	

Average Socially Rational Investment, 1987: $148,948 or $150,000

[a] Emergency medical costs, $177 of total for all user groups.
[b] Legal and Court Costs, $1,045 of total for all user groups.
[c] Gellman Research Associates (See Table 9-A)
[d] Insufficient data, probably .1% or less of all trips.
[e] Emergency medical costs, $185 of total for all user groups.
[f] Legal and Court Costs, $2,018 of total for all user groups.

Table 9-D

Unit Cost of AIS Level 4 (Severe) Aviation Injuries ($1987)

FAA User Group	Individual's Willingness-to-Pay	Foregone Taxes	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
Air Carrier					
Domestic Pass.	413,134	20,724	34,843	23,784	75.4%
Int'l Pass.	413,134	50,348	35,471	23,915	4.8%
Commuter	413,134	20,724	34,843	23,784	5.1%
GA Piston	413,134	47,527	32,330	22,998	9.8%
GA Turbine	413,134	140,983	32,330	22,998	3.2%
Rotorcraft	413,134	78,353	34,843	23,784	1.1%
Air Taxi	413,134	52,658	34,843	23,784	0.6%
Government	413,134	25,003	34,843	23,784	0.0%[d]
Military	413,134	20,003	37,670	24,439	0.0%[d]
Weighted Average:	$413,134	$29,446	$34,546	$23,688	

Average Socially Rational Investment, 1987: $500,814 or $500,000

Table 9-E

Unit Cost of AIS Level 5 (Critical) Aviation Injuries ($1987)

FAA User Group	Individual's Willingness-To-Pay	Foregone Taxes	Total Medical Costs[e]	Legal, Court, Other Admin. Costs[f]	Percent of all Aircraft Trips[c]
Air Carrier					
Domestic Pass.	1,331,475	50,764	105,798	48,625	75.4%
Int'l Pass.	1,331,475	123,333	107,716	48,756	4.8%
Commuter	1,331,475	50,764	105,798	48,625	5.1%
GA Piston	1,331,475	116,424	98,125	47,839	9.8%
GA Turbine	1,331,475	345,352	98,125	47,839	3.2%
Rotorcraft	1,331,475	191,933	105,798	48,625	1.1%
Air Taxi	1,331,475	128,993	105,798	48,625	0.6%
Government	1,331,475	61,248	105,798	48,625	0.0%[d]
Military	1,331,475	49,000	114,430	49,279	0.0%[d]
Weighted Average:	$1,331,475	$72,131	$104,892	$48,529	

Average Socially Rational Investment, 1987: $1,557,027 or $1,560,000

[a] Emergency medical costs, $294 of total for all user groups.
[b] Legal and Court Costs, $15,053 of total for all user groups.
[c] Gellman Research Associates (See Table 9-A)
[d] Insufficient data, probably .1% or less of all trips.
[e] Legal and Court Costs, $39,893 of total for all user groups.

Table 9-F

Unit Cost of Maximum Aviation Injuries
($1987)

FAA User Group	Individual's Willingness-to-Pay	Foregone Taxes	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
Air Carrier					
Domestic Pass.	1,577,129	91,522	25,093	48,625	75.4%
Int'l Pass.	1,577,129	237,261	25,093	48,756	4.8%
Commuter	1,577,129	91,522	25,093	48,625	5.1%
GA Piston	1,577,129	216,173	25,093	47,839	9.8%
GA Turbine	1,577,129	716,499	25,093	47,839	3.2%
Rotorcraft	1,577,129	346,032	25,093	48,625	1.1%
Air Taxi	1,577,129	232,557	25,093	48,625	0.6%
Government	1,577,129	110,422	25,093	48,625	0.0%[d]
Military	1,577,129	117,550	25,093	49,279	0.0%[d]
Weighted Average:	$1,577,129	$134,378	$25,093	$48,529[e]	

Average Socially Rational Investment, 1987: $1,785,129 or $1,790,000

a Emergency medical costs, $294 of total for all user groups.
b Legal and Court Costs, $39,893 of total for all user groups.
c Gellman Research Associates (See Table 9-A)
d Insufficient data, probably .1% or less of all trips.
e Social costs are incurred shortly after accident; therefore, there is no time discounting involved.

Table 10-A

Unit Cost of AIS Level 4 (Severe) Spinal Cord Aviation Injuries ($1987)

Degree of Disability/ FAA User Group	Individual's Willingness-to-Pay	Foregone Taxes	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
Quadriplegia:[d]					
Air Carrier					
Domestic Pass.	1,719,071	91,522	223,492	23,784	75.4%
Int'l Pass.	1,719,071	237,261	225,049	23,915	4.8%
Commuter	1,719,071	91,522	223,492	23,784	5.1%
GA Piston	1,719,071	216,173	217,264	22,998	9.8%
GA Turbine	1,719,071	716,499	217,264	22,998	3.2%
Rotorcraft	1,719,071	346,032	223,492	23,784	1.1%
Air Taxi	1,719,071	232,557	223,492	23,784	0.6%
Government	1,719,071	110,422	223,492	23,784	0.0%[e]
Military	1,719,071	117,550	230,498	24,439	0.0%[e]
Weighted Avg:	$1,719,071	$134,378	$222,757	$23,688	

Average Socially Rational Investment, 1987: $2,099,894 or $2,100,000

Degree of Disability/ FAA User Group	Individual's Willingness-to-Pay	Foregone Taxes	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
Paraplegia:					
Air Carrier					
Domestic Pass.	725,479	27,032	142,391	23,784	75.4%
Int'l Pass.	725,479	88,543	143,191	23,915	4.8%
Commuter	725,479	27,032	142,391	23,784	5.1%
GA Piston	725,479	62,117	139,192	22,998	9.8%
GA Turbine	725,479	175,676	139,192	22,998	3.2%
Rotorcraft	725,479	125,926	142,391	23,784	1.1%
Air Taxi	725,479	87,276	142,391	23,784	0.6%
Government	725,479	32,615	142,391	23,784	0.0%[e]
Military	725,479	29,352	145,990	24,439	0.0%[e]
Weighted Average:	$725,479	$39,629	$142,013	$23,688	

Average Socially Rational Investment, 1987: $930,810 or $930,000

[a] Emergency medical costs, $294 of total for all user groups.
[b] Legal and Court Costs, $15,053 of total for all user groups.
[c] Gellman Research Associates (See Table 9-A)
[d] Individual assumed to be permanently and totally disabled.
[e] Insufficient data, probably .1% or less of all trips.

Table 10-B

Unit Cost of AIS Level 5 (Critical) Spinal Cord Aviation Injuries
($1987)

Degree of Disability/ FAA User Group	Individual's Willingness-to-Pay	Foregone Taxes	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
Quadriplegia:[d]					
Air Carrier					
Domestic Pass.	1,719,071	91,522	309,922	48,625	75.4%
Int'l Pass.	1,719,071	237,261	312,236	48,756	4.8%
Commuter	1,719,071	91,522	309,922	48,625	5.1%
GA Piston	1,719,071	216,173	300,666	47,839	9.8%
GA Turbine	1,719,071	716,499	300,666	47,839	3.2%
Rotorcraft	1,719,071	346,032	309,922	48,625	1.1%
Air Taxi	1,719,071	232,557	309,922	48,625	0.6%
Government	1,719,071	110,422	309,922	48,625	0.0%[e]
Military	1,719,071	117,550	320,336	49,279	0.0%[e]
Weighted Avg:	$1,719,071	$134,378	$308,830	$48,529	

Average Socially Rational Investment, 1987: $2,210,808 or $2,210,000

Paraplegia:					
Air Carrier					
Domestic Pass.	835,878	43,143	187,820	48,625	75.4%
Int'l Pass.	835,878	141,311	189,174	48,756	4.8%
Commuter	835,878	43,143	187,820	48,625	5.1%
GA Piston	835,878	99,136	182,402	47,839	9.8%
GA Turbine	835,878	280,371	182,402	47,839	3.2%
Rotorcraft	835,878	200,973	187,820	48,625	1.1%
Air Taxi	835,878	139,289	187,820	48,625	0.6%
Government	835,878	52,054	187,820	48,625	0.0%[e]
Military	835,878	46,844	193,914	49,279	0.0%[e]
Weighted Average:	$835,878	$63,246	$187,180	$48,529	

Average Socially Rational Investment, 1987: $1,134,834 or $1,130,000

[a] Emergency medical costs, $294 of total for all user groups.
[b] Legal and Court Costs, $39,893 of total for all user groups.
[c] Gellman Research Associates (See Table 9-A)
[d] Individual assumed to be permanently and totally disabled.
[e] Insufficient data, probably .1% or less of all trips.

Table 10-C

Unit Cost of AIS Level 4 (Severe) Head Aviation Injuries
($1987)

Degree of Disability/ FAA User Group	Individual's Willingness-to-Pay	Foregone Taxes	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
Total Disability:					
Air Carrier					
Domestic Pass.	1,845,241	91,522	412,404	23,784	75.4%
Int'l Pass.	1,845,241	237,261	417,938	23,915	4.8%
Commuter	1,845,241	91,522	412,404	23,784	5.1%
GA Piston	1,845,241	216,173	390,265	22,998	9.8%
GA Turbine	1,845,241	716,499	390,265	22,998	3.2%
Rotorcraft	1,845,241	346,032	412,404	23,784	1.1%
Air Taxi	1,845,241	232,557	412,404	23,784	0.6%
Government	1,845,241	110,422	412,404	23,784	0.0%[d]
Military	1,845,241	117,550	437,309	24,439	0.0%[d]
Weighted Avg:	$1,845,241	$134,378	$409,791	$23,688	

Average Socially Rational Investment, 1987: $2,413,098 or $2,410,000

Degree of Disability/ FAA User Group	Individual's Willingness-to-Pay	Foregone Taxes	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
Partial Disability:					
Air Carrier					
Domestic Pass.	236,569	13,926	49,348	23,784	75.4%
Int'l Pass.	236,569	45,613	49,774	23,915	4.8%
Commuter	236,569	13,926	49,348	23,784	5.1%
GA Piston	236,569	32,000	47,642	22,998	9.8%
GA Turbine	236,569	90,500	47,642	22,998	3.2%
Rotorcraft	236,569	64,871	49,348	23,784	1.1%
Air Taxi	236,569	44,960	49,348	23,784	0.6%
Government	236,569	16,802	49,348	23,784	0.0%[d]
Military	236,569	15,121	51,267	24,439	0.0%[d]
Weighted Avg:	$236,569	$20,415	$49,146	$23,688	

Average Socially Rational Investment, 1987: $329,819 or $330,000

[a] Emergency medical costs, $294 of total for all user groups.
[b] Legal and Court Costs, $15,053 of total for all user groups.
[c] Gellman Research Associates (See Table 9-A)
[d] Insufficient data, probably .1% or less of all trips.

Table 10-D

Unit Cost of AIS Level 5 (Critical) Head Aviation Injuries
($1987)

Degree of Disability/ FAA User Group	Individual's Willingness-to-Pay	Foregone Taxes	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
Total Disability:					
Air Carrier					
Domestic Pass.	1,845,241	91,522	461,618	23,784	75.4%
Int'l Pass.	1,845,241	237,261	467,504	23,915	4.8%
Commuter	1,845,241	91,522	461,618	23,784	5.1%
GA Piston	1,845,241	216,173	438,072	22,998	9.8%
GA Turbine	1,845,241	716,499	438,072	22,998	3.2%
Rotorcraft	1,845,241	346,032	461,618	23,784	1.1%
Air Taxi	1,845,241	232,557	461,618	23,784	0.6%
Government	1,845,241	110,422	461,618	23,784	0.0%[d]
Military	1,845,241	117,550	488,107	24,439	0.0%[d]
Weighted Avg:	$1,845,241	$134,378	$458,839	$23,688	

Average Socially Rational Investment, 1987: $2,462,146 or $2,460,000

Degree of Disability/ FAA User Group	Individual's Willingness-to-Pay	Foregone Taxes	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
Partial Disability:					
Air Carrier					
Domestic Pass.	977,820	25,940	133,648	23,784	75.4%
Int'l Pass.	977,820	84,966	134,831	23,915	4.8%
Commuter	977,820	25,940	133,648	23,784	5.1%
GA Piston	977,820	59,607	128,913	22,998	9.8%
GA Turbine	977,820	168,578	128,913	22,998	3.2%
Rotorcraft	977,820	120,838	133,648	23,784	1.1%
Air Taxi	977,820	83,750	133,648	23,784	0.6%
Government	977,820	31,297	133,648	23,784	0.0%[d]
Military	977,820	28,166	138,974	24,439	0.0%[d]
Weighted Avg:	$977,820	$38,028	$133,089	$23,688	

Average Socially Rational Investment, 1987: $1,172,625 or $1,170,000

[a] Emergency medical costs, $294 of total for all user groups.
[b] Legal and Court Costs, $39,893 of total for all user groups.
[c] Gellman Research Associates (See Table 9-A)
[d] Insufficient data, probably .1% or less of all trips.

Table 10-E

Unit Cost of AIS Level 4 and Level 5 Burn Aviation Injuries
($1987)

Degree of Disability/ FAA User Group	Individual's Willingness-to-Pay	Foregone Taxes	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
AIS Level 4 Burns:					
Air Carrier					
Domestic Pass.	2,176,438	13,926	49,348	23,784	75.4%
Int'l Pass.	2,176,438	45,613	49,774	23,915	4.8%
Commuter	2,176,438	13,926	49,348	23,784	5.1%
GA Piston	2,176,438	32,000	47,642	22,998	9.8%
GA Turbine	2,176,438	90,500	47,642	22,998	3.2%
Rotorcraft	2,176,438	64,871	49,348	23,784	1.1%
Air Taxi	2,176,438	44,960	49,348	23,784	0.6%
Government	2,176,438	16,802	49,348	23,784	0.0%[d]
Military	2,176,438	15,121	51,267	24,439	0.0%[d]
Weighted Avg:	$2,176,438	$20,415	$49,146	$23,688	

Average Socially Rational Investment, 1987: $2,269,687 or $2,270,000

Degree of Disability/ FAA User Group	Individual's Willingness-to-Pay	Foregone Taxes	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
AIS Level 5 Burns:					
Air Carrier					
Domestic Pass.	2,176,438	25,940	133,648	48,625	75.4%
Int'l Pass.	2,176,438	84,966	134,831	48,756	4.8%
Commuter	2,176,438	25,940	133,648	48,625	5.1%
GA Piston	2,176,438	59,607	128,913	47,839	9.8%
GA Turbine	2,176,438	168,578	128,913	47,839	3.2%
Rotorcraft	2,176,438	120,838	133,648	48,625	1.1%
Air Taxi	2,176,438	83,750	133,648	48,625	0.6%
Government	2,176,438	31,297	133,648	48,625	0.0%[d]
Military	2,176,438	28,166	138,974	49,279	0.0%[d]
Weighted Avg:	$2,176,438	$38,028	$133,089	$48,529	

Average Socially Rational Investment, 1987: $2,396,083 or $2,400,000

[a] Emergency medical costs, $294 of total for all user groups.
[b] Legal and Court Costs, $15,053 of total for all user groups, AIS 4 Burns.
Legal and Court Costs, $39,893 of total for all user groups, AIS 5 Burns.
[c] Gellman Research Associates (See Table 9-A)
[d] Insufficient data, probably .1% or less of all trips.

E. Incidence-Weighted Average Cost of Injuries

It would be desirable to find some weighting procedure which would give an average cost of a "serious" injury. Before 1989, NTSB accident records indicate injury levels merely by none, minor, serious and fatal. As of January 31, 1989, all injury records will further be classified under the Abbreviated Injury Scale. Nine codes are available to investigators covering the range from no injury to injury of unknown severity. Of those sample accident records filed between January 1, 1983 and December 31, 1986, detailed injury information was available from Form 6120.4, Supplement K for 4142 occupants. Of this total, 3105 were not injured, 186 had minor injuries, and 851 had injuries ranging from moderate to maximum. The results given in Table 9-A are sufficient in the case of minor (NTSB and AIS level 1) injuries. Table 11 uses the sample incidence of different injury levels from 1983 through 1986 to obtain an overall weighted average for the cost of "serious" aviation-related injuries. No additional information is available for the special injuries considered in Tables 10-A through 10-E.

Table 11

Average Socially Rational Investment to Avoid a "Serious" Aviation Injury ($1987)

AIS/NTSB Injury Level	Incidence	Injury Cost by Level
2 (Moderate)	100	$21,838
3 (Serious)	345	148,948
4 (Severe)	99	500,814
5 (Critical)	99	1,557,027
Maximum	208	1,785,129
Weighted Average:		$738,665 or $740,000

SECTION 4: AIRCRAFT CAPACITY AND UTILIZATION FACTORS

A. Introduction

Aircraft capacity and utilization factors apply to the evaluation of FAA investment and regulatory programs which effect time spend in air travel, system capacity and utilization. The utilization of available capacity effects the benefits or costs accrued directly by aircraft operators and indirectly by users and society in the form of fares and taxes.

The aircraft capacity and utilization factors outlined in this section are identified for air carrier and general aviation aircraft. Capacity and utilization factors for large air carrier aircraft for 1985-1987, weighted by airborne hours, are derived by equipment type and for the total air carrier fleet. The factors evaluated are:

Aircraft seating capacity,
Number of crew members (including flight attendants)
Cargo capacity (tons),
Passenger load factor (percent),
Cargo load factor (percent),
Daily utilization (revenue hours airborne per day), and
Off-on speed (miles per hour).

Data limitations do not allow a similar evaluation of these factors for turboprop, piston and smaller turbojet/fan aircraft used in commuter/regional air service.

General aviation aircraft capacity and utilization factors for 1984 and 1987 are derived for FAA aircraft types and for fleet profiles weighted by use. The factors evaluated are:

Seating capacity,
Passenger load factor (including pilot, in percent), and
Useful load (pounds).

Other average flight characteristics, i.e. landings per flight, flight time and flight speed, appear in the 1984 General Aviation Pilot and Aircraft Activity Survey[105] (GA Pilot Survey). Research for this section determined that this source could not be improved upon for the characteristics indicated.

Non-classified information on capacity and utilization factors for military aircraft is not available. As a result, no estimates are provided for military aircraft.

B. Air Carrier Aircraft

Data availability limited the evaluation of capacity and utilization factors for air carrier aircraft to the following large aircraft models: Airbus 300; BAE 146; Boeing 727, 737, 747, 757, 767; Lockheed L-1011; and McDonnell Douglas DC-8, DC-9, DC-10 and MD-80. No source was found with detailed yearly aggregate information on capacity and utilization factors for turboprop, piston and smaller turbofan aircraft in scheduled service. Department of Transportation Form 298 capacity and utilization information on commuter air carriers is not required to be specific to aircraft type or model. This information is generally reported as a corporate aggregate. Consequently, type averages cannot be obtained for commuter type aircraft.

The information for this section was derived from three sources:

1. Aviation Week and Space Technology[106] publishes quarterly tabular reports of capacity and utilization factors and variable operating costs for the most common wide- and narrow-body large aircraft types in operation by major, national and large regional carriers. This information is prepared by I.P. Sharpe Associates for Aviation Week using the DOT Form 41's submitted by the carriers.
2. U.S. Department of Transportation Form 41, Schedule T-2. Because Aviation Week contained no information on four-engine narrow body turbofans, capacity and utilization information for these aircraft was estimated directly from DOT Form 41's on file.
3. FAA Statistical Handbook of Aviation[107] (Statistical Handbook) gives aggregated yearly flight hour totals by manufacturer and model for all aircraft used by air carriers.

The publication which was traditionally used by the FAA to summarize air carrier capacity and utilization factors, the Aircraft Operating Cost and Performance Report,[108] ceased publication in 1984. To maintain the availability of yearly estimates, the air carrier information in this section covers the period 1985-1987. At the time of writing, information was available only for the first and second quarters of 1987. Also, weighted averages for 1987 are based on total flight hours reported for 1986 in the Statistical Handbook.

Unfortunately, no current publication provides the same level of capacity and utilization information for large aircraft by type of service (for example domestic vs. international passenger service) as was available in the Aircraft Operating Cost and Performance Report. Because of the limitations of data currently published on air carrier capacity and utilization, the capacity and utilization factor results in this study will be limited to overall averages by equipment type.

The Aviation Week tables contain quarterly information, aggregated by airline, on capacity and utilization factors for the ten most common aircraft models in the air carrier fleet: Boeing 727, 737, 757, and 767; McDonnell Douglas DC-9, DC-10 and MD-80; Airbus A300; and Lockheed L-1011. Most airlines operating these aircraft models and filing DOT Form 41 are represented in these reports. The seating capacity, passenger load and daily

utilization values appear directly in the Aviation Week tables. The other values were calculated as follows:

Crew members = one flight attendant per 45 seats (rounded up) plus number in flight crew[109]

Cargo capacity (tons) = Available Ton-Miles / Revenue Miles

Cargo load (%) = (Revenue Ton-Miles / Available Ton-Miles) x 100

Off-on speed = Revenue Miles / Revenue Hours

Quarterly capacity and utilization information for four engine narrow body turbofans was obtained directly from individual Form 41's filed with the Department of Transportation.

A weighted average of quarterly capacity and utilization factors by model was obtained using the total revenue hours reported for each model by its operators. A yearly model average was calculated and weighted by total yearly flight hours by model, as reported in the Statistical Handbook, to give weighted averages by equipment type. Yearly averages for 1987 for the models used in these estimates appear in Section 10, Appendix Table 1.

Tables 12 through 14 list calendar year estimates of air carrier capacity and utilization factors by equipment type for 1985-1987. Total flight hours by equipment type reported in the Statistical Handbook equals total airborne activity indicated in these tables. Overall fleet averages of capacity and utilization factors are weighted by airborne activity hours by equipment type.

Fleet averages for seat and cargo capacity show some increase over the three year period. Overall fleet changes in these factors are largely the result of the steady increase in size of two-engine narrow body aircraft. Four-engine narrow body averages appear unpredictable because of offsetting changes in the number of active BAE 146 and DC-8 aircraft. As the number of BAE 146 aircraft in service continues to increase, capacity averages for this type will continue to decline. Averages for this equipment type are more misleading than those for other types because the two dominant models, the BAE 146 and DC-8, differ greatly in size.

Passenger and cargo loads and daily aircraft utilization show small overall increases over time. This is to be expected, as the period of adjustment to deregulation gives way to an emphasis on maximum utilization of resources. It is interesting that average off-on speed by type and for the entire fleet shows such small changes over time. This indicates a reasonable overall stability in the combination of factors (i.e. stage length and equipment type) which contributes to off-on speed.

C. General Aviation Aircraft

Weighted capacity and utilization factors for general aviation aircraft were derived from three sources:

1. The Aircraft Bluebook - Price Digest[110] (Bluebook) provides seating capacity and aircraft weight information by aircraft model year for most of the active aircraft make/models in the U.S. general aviation fleet.
2. The General Aviation Activity and Avionics Survey[111] (G.A. Survey) consists of a random sample yearly survey of the registered general aviation population. The summary information appearing in the survey publication used in this section included: total hours of flight for all active aircraft by make/model and total hours of flight by use category by FAA type classification.
3. The National Transportation Safety Board Aviation Accident Data System[112] (NTSB Data) provided a yearly list of the number of injuries (including occupants not injured) for general aviation accidents and incidents for 1982-1987.

An existing document, General Aviation Pilot and Aircraft Activity Survey (most recently containing 1984 data, now discontinued), contains the following capacity and utilization information:

Landings per flight,
Flight time,
Flight speed,
Seats available,
Seats occupied, and
Passenger load factor.

This document still represents the best sample information available for landings, flight time and flight speed. Because no improvement can be made on these estimates, and because more recent data does not exist for these utilization characteristics, this study considers only the following three general aviation capacity and utilization factors:

Seats available,
Passenger load factor, and
Maximum useful aircraft load in pounds.

The estimation of weighted capacity and utilization factors for the general aviation fleet began with estimates of capacity and utilization factors for approximately 110 different make/models of the most common general aviation aircraft. Estimates were only done for 1984 and 1987 because of the complexity of working up the data for a large number of aircraft models and the likelihood that trends for changes in these factors for most FAA general aviation aircraft types would be more stable over time than is the case with air carrier aircraft. Estimates for 1987 are based on 1987 factor estimates by make/model weighted by flight hour estimates in the 1986 GA Survey.

For regulatory and investment decisions requiring capacity and utilization estimates, actual aircraft use is the appropriate weighting technique. Consequently, flight hour estimates are used to weight FAA type and total fleet averages. To produce weighted averages by type, factors and flight hours were determined at the make/model level (for example, maximum number of seats and yearly flight hours for the Cessna 172 would be used).

Model technical information contained in the Bluebook provided maximum seats and maximum useful load by make/model. Maximum useful load was calculated to be aircraft maximum gross weight minus empty weight. For rotorcraft, maximum gross weight was taken to include an external load where appropriate.

Estimates of the average number of seats occupied by make/model were based on NTSB general aviation accidents and incidents reported over a multi-year period. It is assumed that on average the number of occupants in a given aircraft model which has experienced an accident or incident is typical of the normal occupancy of that model aircraft. The occupancy estimates for 1984 are based on average occupancy by make/model for accidents and incidents which occurred in 1982, 1983 and 1984. Similarly, the 1987 estimates are based on 1985-1987 information. The three-year period was selected for each of the two estimated time periods so as to increase the accident/incident sample size. Passenger load by make/model is then calculated to be the average number of seats occupied as a percent of the maximum available seats.

Some make/models showed no accidents at all during this sample time period, and others had less than three accidents or incidents per year (for a total sample smaller than six cases). These special cases were handled as follows:

Turboprop, 2-engine, 1-12 seats (FAA-APO type 6) - Average occupancy values were developed for Beech 100, 200 and 300 aircraft as a group; and average occupancy values were developed for all 12-seat aircraft as a group. These values were assigned to each make/model in the respective groups. Values were developed by make/model for all other type 6 aircraft.

Turboprop, 2-engine, 13+ seats (FAA-APO type 7) - Average occupancy values were developed for all type 7 aircraft. These values were assigned to each make/model in the group.

Turbojet/fan, 2-engine (FAA-APO type 9) - Average occupancy values were developed for all type 9 aircraft. These values were assigned to each make/model in the group.

Rotorcraft, Turbine (FAA-APO type 12) - Average occupancy values were developed for all 14+ seat aircraft. These values were assigned to each 14+ seat type 12 make/model.

The capacity and utilization factor estimates used in this study by make/model for 1987 are given in Section 10, Appendix Table 2.

Table 15 presents general aviation capacity and utilization factor estimates by aircraft type weighted by total hours flown for 1984 and 1987.

Tables 16-A through 18-B give capacity and utilization factor estimates for 1984 and 1987 weighted by general aviation fleet use profiles. For these tables, the total active fleet by aircraft type was given a relative share of each use profile based on total hours flown by each type by FAA use category indicated in the G.A. Survey. Three use categories were developed for the use profiles indicated in these Tables: air taxi, commuter and all other (personal, business, aerial application, etc.). These use categories were grouped in various ways to produce six different weighted estimates of general aviation capacity and utilization factors:

1. conventional general aviation including air taxi and commuter,
2. conventional general aviation excluding commuter, but including air taxi,
3. conventional general aviation excluding both air taxi and commuter,
4. air taxi and commuter only,
5. air taxi only, and
6. commuter only.

Tables 16-A and 16-B present maximum seating capacity estimates for general aviation use profiles for 1984 and 1987 weighted by total hours flown. These estimates demonstrate that in general the active general aviation fleet is tending toward aircraft with a larger seating capacity. The use profile estimates, however, demonstrate that this overall trend is most heavily influenced by the increasing share of total general aviation flight hours by aircraft used in the commuter and air taxi service.

Tables 17-A and 17-B present estimates for the percent of available seats occupied for general aviation use profiles for 1984 and 1987 weighted by total hours flown. These estimates show a clear reduction in the occupancy percentage for all use profiles except commuter flights. This observation, combined with observed reductions in flight hours per aircraft (in uses other than air taxi and commuter), indicates an overall decline of general aviation flight per capita.

Tables 18-A and 18-B present average useful load estimates for general aviation use profiles for 1984 and 1987 weighted by total hours flown. These estimates show a clear increase in the average size of the aircraft most in use. The trend shown in Tables 16-A and 16-B indicates that this size factor is not demonstrated by large increases in available seating, but rather indicates greater relative use of larger, higher performance aircraft. This observation is supported by variable operating cost and replacement cost estimates presented in Section 5 and Section 6.

Table 12

CY 1985 AIR CARRIER CAPACITY AND UTILIZATION BY EQUIPMENT TYPE

Equipment Type	Average Seat Capacity (seats)	Number of Crew Members	Average Cargo Capacity (tons)	Passenger Load Factor (percent)	Cargo Load Factor (percent)	Daily Aircraft Utilization (hours/day)	Off-On Speed (mph)	Fleet Airborne Hours by Type
Turbofan, 4-Engine, Wide Body	365.2	12	57.5	65.8	56.9	10.5	513	537,954
Turbofan, 4-Engine, Narrow Body	182.0	8	23.4	59.3	47.9	7.2	419	279,104
Turbofan, 3-Engine, Wide Body	272.1	10	38.7	64.1	55.4	8.6	490	853,509
Turbofan, 3-Engine, Narrow Body	148.7	7	18.0	57.9	51.4	8.2	436	2,989,848
Turbofan, 2-Engine, Wide Body	220.2	7	31.5	63.9	53.6	9.0	465	329,984
Turbofan, 2-Engine, Narrow Body	116.3	5	14.1	57.3	49.9	7.8	394	3,238,502
Weighted Average[a]:	166.9	7	21.9	59.1	51.5	8.2	430	8,228,901

[a]Weighted by total fleet airborne hours by type

Table 13

CY 1986 AIR CARRIER CAPACITY AND UTILIZATION BY EQUIPMENT TYPE

Equipment Type	Average Seat Capacity (seats)	Number of Crew Members	Average Cargo Capacity (tons)	Passenger Load Factor (percent)	Cargo Load Factor (percent)	Daily Aircraft Utilization (hours/day)	Off-One Speed (mph)	Fleet Airborne Hours by Type
Turbofan, 4-Engine, Wide Body	369.4	12	57.3	59.3	55.2	10.0	506	559,137
Turbofan, 4-Engine, Narrow Body	169.0	7	17.6	64.1	53.4	8.2	427	362,272
Turbofan, 3-Engine, Wide Body	277.1	10	39.2	64.5	56.1	9.0	487	924,000
Turbofan, 3-Engine, Narrow Body	148.3	7	18.1	59.7	52.7	8.1	430	3,036,233
Turbofan, 2-Engine, Wide Body	219.8	7	31.1	62.8	54.8	9.1	468	391,179
Turbofan, 2-Engine, Narrow Body	119.3	5	14.7	58.8	49.3	8.0	397	3,666,088
Weighted Average[a]:	167.5	7	21.9	60.1	51.9	8.3	429	8,938,909

[a]Weighted by total fleet airborne hours by type

Table 14

CY 1987 AIR CARRIER CAPACITY AND UTILIZATION BY EQUIPMENT TYPE

Equipment Type	Average Seat Capacity (seats)	Number of Crew Members	Average Cargo Capacity (tons)	Passenger Load Factor (percent)	Cargo Load Factor (percent)	Daily Aircraft Utilization (hours/day)	Off-One Speed (mph)	Fleet Airborne Hours by Type
Turbofan, 4-Engine, Wide Body	369.2	12	57.2	63.5	59.8	10.3	509	559,137
Turbofan, 4-Engine, Narrow Body	168.6	7	21.7	65.1	53.3	8.6	427	362,272
Turbofan, 3-Engine, Wide Body	278.4	10	38.7	66.2	57.3	9.2	493	924,000
Turbofan, 3-Engine, Narrow Body	148.8	7	18.4	61.4	53.0	8.3	429	3,036,233
Turbofan, 2-Engine, Wide Body	220.3	7	33.3	65.6	51.4	9.8	459	391,179
Turbofan, 2-Engine, Narrow Body	126.6	5	14.9	59.5	50.2	8.0	398	3,666,088
Weighted Average[b]:	170.8	7	22.3	61.6	52.7	8.4	429	8,938,909

[a]CY 1986 Data

[b]Weighted by total fleet airborne hours by type

Table 15

GENERAL AVIATION AIRCRAFT CAPACITY AND UTILIZATION BY AIRCRAFT TYPE, WEIGHTED BY HOURS FLOWN

Aircraft Type	Year	Average Seat Capacity	Average Seats Occupied (%)	Total Useful Load (pounds)
Fixed Wing				
(1) Piston, 1-Engine, 1-3 Seats	1984	1.8	84.4	709
	1987	1.8	76.8	731
(2) Piston, 1-Engine, 4+ Seats	1984	4.3	57.7	1,168
	1987	4.3	47.7	1,162
(3) Piston, 2-Engine, 1-6 Seats	1984	6.2	38.6	2,170
	1987	6.1	42.5	2,122
(4) Piston, 2-Engine, 7+ Seats	1984	7.9	44.2	2,359
	1987	7.9	36.6	2,356
(5) Other Piston[a]				
(6) Turboprop, 2-Engine, 1-12 Seats	1984	10.3	51.9	4,325
	1987	10.7	35.7	4,526
(7) Turboprop, 2-Engine, 13+ Seats	1984	20.9	36.1	4,985
	1987	20.5	53.7	6,358
(8) Other Turboprop[a]				
(9) Turbojet, 2-Engine	1984	8.8	41.0	7,914
	1987	8.9	35.1	8,126
(10) Other Turbojet[a]				
Rotorcraft				
(11) Piston	1984	2.9	65.4	921
	1987	3.1	57.6	1,009
(12) Turbine	1984	5.9	50.9	1,924
	1987	6.4	51.1	2,298

[a]Insufficient population to provide reliable estimates.

Table 16-A

MAXIMUM SEATING CAPACITY FOR GENERAL AVIATION AIRCRAFT PROFILES, WEIGHTED BY HOURS FLOWN - 1984

Aircraft Type Category	Maximum Seats	G.A. Including Taxi/Comm. Relative Hours Flown	G.A. Including Taxi/Comm. Ext.	G.A. Excluding Commuter Relative Hours Flown	G.A. Excluding Commuter Ext.	G.A. Excluding Taxi and Comm. Relative Hours Flown	G.A. Excluding Taxi and Comm. Ext.	Air Taxi and Commuter Relative Hours Flown	Air Taxi and Commuter Ext.	Air Taxi Only Relative Hours Flown	Air Taxi Only Ext.	Commuter Only Relative Hours Flown	Commuter Only Ext.
1	1.8	0.2428	0.44	0.2529	0.46	0.2770	0.51	0.0000	0.00	0.0000	0.00	0.0000	0.00
2	4.3	0.4218	1.83	0.4368	1.89	0.4582	1.99	0.1642	0.71	0.2127	0.92	0.0621	0.27
3	6.2	0.0844	0.52	0.0842	0.52	0.0776	0.48	0.1327	0.82	0.1534	0.95	0.0892	0.55
4	7.9	0.0738	0.59	0.0623	0.49	0.0454	0.36	0.2728	2.17	0.2384	1.89	0.3452	2.74
6	10.3	0.0485	0.50	0.0492	0.51	0.0483	0.50	0.0496	0.51	0.0583	0.60	0.0312	0.32
7	20.9	0.0208	0.44	0.0043	0.09	0.0044	0.09	0.1373	2.87	0.0036	0.08	0.4184	8.74
9	8.8	0.0376	0.33	0.0371	0.33	0.0374	0.33	0.0386	0.34	0.0340	0.30	0.0482	0.42
11	2.9	0.0167	0.05	0.0174	0.05	0.0187	0.05	0.0032	0.01	0.0047	0.01	0.0000	0.00
12	5.9	0.0538	0.32	0.0558	0.33	0.0330	0.19	0.2017	1.19	0.2949	1.74	0.0058	0.03
Total:			5.0		4.7		4.5		8.6		6.5		13.1

Table 16-B

MAXIMUM SEATING CAPACITY FOR GENERAL AVIATION AIRCRAFT PROFILES, WEIGHTED BY HOURS FLOWN - 1987

Aircraft Type Category	Maximum Seats	G.A. Including Taxi/Comm.		G.A. Excluding Commuter		G.A. Excluding Taxi and Comm.		Air Taxi and Commuter		Air Taxi Only		Commuter Only	
		Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.
1	1.8	0.2313	0.42	0.2469	0.45	0.2692	0.49	0.0153	0.03	0.0265	0.05	0.0000	0.00
2	4.3	0.4171	1.79	0.4359	1.87	0.4581	1.96	0.1832	0.78	0.2168	0.93	0.1376	0.59
3	6.1	0.0827	0.51	0.0870	0.53	0.0806	0.49	0.0948	0.58	0.1504	0.92	0.0191	0.12
4	7.9	0.0625	0.49	0.0547	0.43	0.0407	0.32	0.1861	1.47	0.1927	1.52	0.1770	1.40
6	10.7	0.0487	0.52	0.0433	0.46	0.0417	0.45	0.0886	0.95	0.0596	0.64	0.1282	1.37
7	20.5	0.0340	0.70	0.0041	0.08	0.0035	0.07	0.2074	4.26	0.0103	0.21	0.4758	9.77
9	8.9	0.0463	0.41	0.0494	0.44	0.0475	0.42	0.0393	0.35	0.0681	0.60	0.0002	0.00
11	3.1	0.0238	0.07	0.0253	0.08	0.0274	0.08	0.0031	0.01	0.0049	0.02	0.0006	0.00
12	6.4	0.0538	0.35	0.0533	0.34	0.0313	0.20	0.1822	1.17	0.2708	1.74	0.0615	0.39
Total:			5.3		4.7		4.5		9.6		6.6		13.6

Table 17-A

PERCENT OF AVAILABLE SEATS OCCUPIED FOR GENERAL AVIATION AIRCRAFT PROFILES, WEIGHTED BY HOURS FLOWN - 1984

Aircraft Type Category	Percent of Seats Occupied	G.A. Including Taxi/Comm.		G.A. Excluding Commuter		G.A. Excluding Taxi and Comm.		Air Taxi and Commuter		Air Taxi Only		Commuter Only	
		Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.
1	84.4	0.2428	20.5	0.2529	21.3	0.2770	23.4	0.0000	0.0	0.0000	0.0	0.0000	0.0
2	57.7	0.4218	24.3	0.4368	25.2	0.4582	26.4	0.1642	9.5	0.2127	12.3	0.0621	3.6
3	38.6	0.0844	3.3	0.0842	3.3	0.0776	3.0	0.1327	5.1	0.1534	5.9	0.0892	3.4
4	44.2	0.0738	3.3	0.0623	2.8	0.0454	2.0	0.2728	12.1	0.2384	10.5	0.3452	15.3
6	51.9	0.0485	2.5	0.0492	2.6	0.0483	2.5	0.0496	2.6	0.0583	3.0	0.0312	1.6
7	36.1	0.0208	0.8	0.0043	0.2	0.0044	0.2	0.1373	5.0	0.0036	0.1	0.4184	15.1
9	41.0	0.0376	1.5	0.0371	1.5	0.0374	1.5	0.0386	1.6	0.0340	1.4	0.0482	2.0
11	65.4	0.0167	1.1	0.0174	1.1	0.0187	1.2	0.0032	0.2	0.0047	0.3	0.0000	0.0
12	50.9	0.0538	2.7	0.0558	2.8	0.0330	1.7	0.2017	10.3	0.2949	15.0	0.0058	0.3
Total:			60.0		60.7		61.9		46.2		48.6		41.3

Table 17-B

PERCENT OF AVAILABLE SEATS OCCUPIED FOR GENERAL AVIATION AIRCRAFT PROFILES, WEIGHTED BY HOURS FLOWN - 1987

Aircraft Type Category	Percent of Seats Occupied	G.A. Including Taxi/Comm.		G.A. Excluding Commuter		G.A. Excluding Taxi and Comm.		Air Taxi and Commuter		Air Taxi Only		Commuter Only	
		Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.
1	76.[illegible]	0.2313	17.8	0.2469	19.0	0.2692	20.7	0.0153	1.2	0.0265	2.0	0.0000	0.0
2	47.[illegible]	0.4171	19.9	0.4359	20.8	0.4581	21.9	0.1832	8.7	0.2168	10.4	0.1376	6.6
3	42.5	0.0827	3.5	0.0870	3.7	0.0806	3.4	0.0948	4.0	0.1504	6.4	0.0191	0.8
4	36.6	0.0625	2.3	0.0547	2.0	0.0407	1.5	0.1861	6.8	0.1927	7.0	0.1770	6.5
6	35.7	0.0487	1.7	0.0433	1.5	0.0417	1.5	0.0886	3.2	0.0596	2.1	0.1282	4.6
7	53.7	0.0340	1.8	0.0041	0.2	0.0035	0.2	0.2074	11.1	0.0103	0.6	0.4758	25.5
9	35.1	0.0463	1.6	0.0494	1.7	0.0475	1.7	0.0393	1.4	0.0681	2.4	0.0002	0.0
11	57.6	0.0238	1.4	0.0253	1.5	0.0274	1.6	0.0031	0.2	0.0049	0.3	0.0006	0.0
12	51.1	0.0538	2.7	0.0533	2.7	0.0313	1.6	0.1822	9.3	0.2708	13.8	0.0615	3.1
Total:			52.8		53.2		54.0		45.9		45.0		47.2

Table 18-A

AVERAGE USEFUL LOAD FOR GENERAL AVIATION AIRCRAFT PROFILES, WEIGHTED BY HOURS FLOWN - 1984

Aircraft Type Category	Average Useful Load (pounds)	G.A. Including Taxi/Comm.		G.A. Excluding Commuter		G.A. Excluding Taxi and Comm.		Air Taxi and Commuter		Air Taxi Only		Commuter Only	
		Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.
1	709	0.2428	172.2	0.2529	179.4	0.2770	196.5	0.0000	0.0	0.0000	0.0	0.0000	0.0
2	1168	0.4218	492.9	0.4368	510.3	0.4582	535.4	0.1642	191.8	0.2127	248.5	0.0621	72.6
3	2170	0.0844	183.1	0.0842	182.7	0.0776	168.3	0.1327	287.9	0.1534	332.8	0.0892	193.5
4	2359	0.0738	174.2	0.0623	146.9	0.0454	107.2	0.2728	643.6	0.2384	562.4	0.3452	814.3
6	4325	0.0485	209.8	0.0492	212.9	0.0483	209.1	0.0496	214.3	0.0583	252.1	0.0312	134.8
7	4985	0.0208	103.8	0.0043	21.6	0.0044	21.9	0.1373	684.5	0.0036	18.0	0.4184	2085.3
9	7914	0.0376	297.3	0.0371	293.8	0.0374	296.2	0.0386	305.1	0.0340	268.7	0.0482	381.5
11	921	0.0167	15.4	0.0174	16.1	0.0187	17.2	0.0032	2.9	0.0047	4.3	0.0000	0.0
12	1924	0.0538	103.6	0.0558	107.4	0.0330	63.4	0.2017	388.2	0.2949	567.6	0.0058	11.1
Total:			1752		1671		1615		2718		2255		3693

Table 18-B

AVERAGE USEFUL LOAD FOR GENERAL AVIATION AIRCRAFT PROFILES, WEIGHTED BY HOURS FLOWN - 1987

		G.A. Including Taxi/Comm.		G.A. Excluding Commuter		G.A. Excluding Taxi and Comm.		Air Taxi and Commuter		Air Taxi Only		Commuter Only	
Aircraft Type Category	Useful Load (pounds)	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.
1	731	0.2313	169.1	0.2469	180.5	0.2692	196.8	0.0153	11.2	0.0265	19.4	0.0000	0.0
2	1162	0.4171	484.7	0.4359	506.7	0.4581	532.4	0.1832	213.0	0.2168	251.9	0.1376	160.0
3	2122	0.0827	175.5	0.0870	184.6	0.0806	171.0	0.0948	201.1	0.1504	319.1	0.0191	40.6
4	2356	0.0625	147.1	0.0547	128.9	0.0407	96.0	0.1861	438.4	0.1927	454.0	0.1770	417.1
6	4526	0.0487	220.4	0.0433	196.1	0.0417	188.7	0.0886	401.1	0.0596	269.6	0.1282	580.2
7	6358	0.0340	215.9	0.0041	26.2	0.0035	22.3	0.2074	1318.9	0.0103	65.2	0.4758	3024.8
9	8126	0.0463	376.2	0.0494	401.4	0.0475	386.1	0.0393	319.6	0.0681	553.4	0.0002	1.5
11	1009	0.0238	24.0	0.0253	25.6	0.0274	27.7	0.0031	3.1	0.0049	5.0	0.0006	0.6
12	2298	0.0538	123.7	0.0533	122.5	0.0313	71.9	0.1822	418.6	0.2708	622.3	0.0615	141.3
Total:			1937		1772		1693		3325		2560		4366

SECTION 5: AIRCRAFT VARIABLE OPERATING COSTS

A. Introduction

Aircraft variable operating costs are important factors in the evaluation of FAA investment and regulatory programs which bear on time spent in air travel. The variable operating costs of aircraft effect the benefits or costs accrued directly by aircraft operators and indirectly by users and society in the form of fares and taxes.

The costs outlined in this section are identified for air carrier, general aviation and military aircraft equipment types. Weighted aircraft variable operating costs for 1985-1987 are derived per block hour and airborne hour by air carrier aircraft type and for the total air carrier fleet. General aviation aircraft variable operating costs for 1984 and 1987 are derived for FAA aircraft types and for population and usage weighted fleet profiles. Military variable operating costs by military aircraft type are projected for 1988-1992 in constant 1988 dollars.

Published data on aircraft operating costs commonly contain costs defined as: variable or fixed, and direct or indirect. Variable costs change in proportion to changes in aircraft activity or usage, such as fuel, oil, maintenance and crew costs. Fixed and indirect costs show little or no change in relation to changes in aircraft activity. Such costs include: general and administrative expenses, hanger costs and rental charges based on time periods rather than usage. Published direct costs also include depreciation, lease amortization, insurance and maintenance burden costs which may depend on both the passage of time and the amount of aircraft activity. These costs can be considered "semi-variable."

The purpose of this analysis is to quantify those costs which vary directly with aircraft activity. "Variable operating costs," as used here, include paid flight crew, fuel, oil and direct maintenance of airframe, avionics and engine. Costs having some dependence on the passage of time will be excluded. Semi-variable, fixed and indirect costs will not be included because they depend in some way on the passage of time. Flight crew expenses are included only for air carrier, air commuter and air taxi operations. Costs for crews and passengers for all other operations should be evaluated using the value of time in air travel, addressed in Section 1.

B. Air Carrier Aircraft

The variable operating costs of air carrier aircraft were derived from three sources:

1. Aviation Week and Space Technology[113] publishes quarterly tabular reports of operating costs and utilization characteristics for the most common wide- and narrow-body large aircraft types in operation by major, national and large regional carriers. This information is

prepared by I.P. Sharpe Associates for Aviation Week using the DOT Form 41's submitted by the carriers.

2. U.S. Department of Transportation[114] Forms 298-C and 41. Form 298-C provides operating cost and utilization information for commuter carriers. This information for larger carriers is filed on DOT Form 41.

3. FAA Statistical Handbook of Aviation[115] (Statistical Handbook) gives aggregated yearly flight hour totals by manufacturer and model for all aircraft used by air carriers.

The publication which was traditionally used by the FAA to summarize air carrier variable operating costs, the Aircraft Operating Cost and Performance Report,[116] ceased publication in 1984. No current publication provides the same level of operating cost information for large aircraft by type of service (for example domestic vs. international passenger service). Because of the limitations of data currently published on air carrier operating costs, variable operating cost results in this study will be limited to overall averages by equipment type.

FAA reporting procedures for commuter carriers changed in the 1984-1985 time period. Consequently, 1985 is the first year for which a reasonable number of turboprop and piston engine operators filed Form 298-C operating cost information. To maintain the consistency of estimates for all air carrier aircraft, air carrier variable operating cost results will cover only the period 1985-1987. Further, at the time of writing this study, information was available only for the first and second quarters of 1987. Weighted averages for 1987 are based on total flight hours reported for 1986 in the Statistical Handbook.

The Aviation Week tables contain quarterly information, aggregated by airline, on operating costs for the ten most common aircraft models in the air carrier fleet: Boeing 727, 737, 757, and 767; McDonnell Douglas DC-9, DC-10 and MD-80; Airbus A300; and Lockheed L-1011. Most airlines operating these aircraft models and filing DOT Form 41 are represented in these reports. Quarterly operating cost information for equipment types not included in Aviation Week (four engine narrow body turbojets, turboprop and piston aircraft) was obtained directly from Form 41 and Form 298-C reports filed with the Department of Transportation.

A weighted average of quarterly variable operating costs per block hour by model was obtained using the total quarterly block hours reported for each model by its operators. A yearly model average was calculated and weighted by total yearly flight hours by model, as reported in the Statistical Handbook, to give weighted averages by equipment type. Quarterly and yearly averages for 1987 for the models used in these estimates are presented in Section 10, Appendix Table 3.

Because of the often large difference in operating costs for the Alaskan region, as compared to other regions, operating costs for turboprop and piston aircraft in Alaska were estimated separately. The relative share of flight hours for the Alaskan region for turboprop and piston equipment types

was estimated, by year, from the Form 298-C reports examined for this study. This estimate was used to attribute total reported flight hours for all carriers to either Alaska or all other regions for turboprop and piston engine equipment types.

Tables 19 through 21 list calender year estimates of air carrier variable operating costs by equipment type for 1985-1987. Operating costs are reported by the carriers per revenue block hour. The yearly average ratio of revenue block hours to revenue airborne hours (using the Form 298-C and Aviation Week information) was used to estimate variable operating costs per airborne hour. Total flight hours by equipment type reported in the Statistical Handbook equals total airborne activity indicated in these tables. Total block hour activity is estimated using the ratio calculated above but adjusted to reflect the fact that approximately one-half of one percent of total flight hours are non-revenue. The dollar extensions provide estimates of total calendar year block and airborne variable operating costs. Overall fleet averages of variable operating costs per block and airborne hours are weighted by block and airborne activity hours by equipment type.

Variable operating costs for large aircraft (except 4-engine narrow body in 1987) showed a uniform decline over this time period. The decline in fuel prices was the dominant factor in this trend. Trends in 4-engine narrow body costs can be attributed to the large increase in use of DC-8 aircraft following a period of fleet re-engining (hush kits). Maintenance costs showed clear increases for most types, but direct maintenance represents less than 25% of total variable costs for most aircraft. Average crew costs showed no overall trend. Crew costs for types operated largely by the long established major carriers increased. Crew costs for types being used more by the "post-deregulation" carriers remained stable or decreased.

C. General Aviation Aircraft

The weighted unit variable operating costs of general aviation aircraft were derived from seven sources:

1. The Aircraft Bluebook - Price Digest[117] (Bluebook) provides average retail price, overhaul cost, capacity and performance information (including engine horsepower) by aircraft model year for most of the active aircraft make/models in the U.S. general aviation fleet.

2. The General Aviation Activity and Avionics Survey[118] (G.A. Survey) consists of a random sample yearly survey of the registered general aviation population. The summary information appearing in the survey publication used in this study included: active population by make/model, average fuel consumption per hour by make/model, total hours of flight for all active aircraft by make/model, population by primary use category by FAA type classification and total hours of flight by use category by FAA type classification.

3. The Cessna Pilots Association[119] (CPA) provided operating cost information they have compiled from their membership for eight of the most common Cessna aircraft in the general aviation fleet.

4. The AOPA Fuel Survey Report[120] (AOPA Survey) for 1984 and 1987 provided general aviation fuel costs for the two years considered in this study.

5. The FAA Aviation Forecasts-Fiscal Years 1988-1999[121] (FAA Forecasts) provided maintenance cost indices for multi-engine piston, turboprop and turbojet/fan general aviation aircraft.

6. Crew cost and maintenance estimates for turboprop and small turbojet/fan aircraft discussed in the air carrier section above.

7. The Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs[122] (Economic Values) contained the only estimates of rotorcraft maintenance costs obtainable without conducting a survey to obtain new primary source estimates.

The estimation of weighted variable operating costs for the general aviation fleet began with estimates of variable operating costs for approximately 110 different make/models of the most common general aviation aircraft. Estimates were only done for 1984 and 1987 because of the complexity of working up the data for this number of aircraft and the likelihood that cost trends for most general aviation aircraft types would be more stable over time than is the case with air carrier aircraft. Estimates for 1987 are based on 1987 cost estimates by make/model weighted by population and flight hour estimates in the 1986 GA Survey.

For the purpose of making regulatory and investment decisions involving flight time, it is appropriate in most occasions to use a utilization weight to estimate variable operating costs. A population count weight is also included in this study. The weights used to calculate type and total fleet average costs were determined at the make/model level (for example, depending on the weighting method required, yearly flight hours or active population for the Cessna 172 would be used).

Fuel and oil costs by make/model were estimated by multiplying GA Survey estimates of fuel consumption per hour by AOPA Survey estimates of average fuel costs in 1984 and 1987, using the appropriate type of fuel for each make/model aircraft. Small air carrier cost reports indicate oil costs to be between 1% and 2% of total fuel costs for piston engine aircraft and less than 1% for turboprop aircraft. These estimates of oil use are smaller than the margin of error for most fuel consumption estimates in the GA Survey. Also, the CPA indicates that for many operators of general aviation aircraft, oil use can be considered a semi-variable cost in that the recommended time interval for oil use often elapses well before the recommended number of hours flown. For these reasons, no attempt will be made to adjust the fuel use estimates to specifically reflect oil costs.

Only air commuter and air taxi use profiles will be assigned crew cost estimates. There are no cost reporting requirements for most operators of aircraft in the general aviation fleet with these use profiles. Crew costs were assigned for general aviation aircraft types by analogy to the costs

reported by small air carriers filing Form 298-C for the piston, turboprop and small turbojet/fan aircraft operated by them. Costs for 1984 were adjusted from 1985 Form 298-C reports using the Consumer Price Index (CPI). Crew costs for rotorcraft were assigned such that piston rotorcraft crew costs equal fixed wing type 1 and 2 costs and turbine rotorcraft crew costs equal fixed wing type 3 and 4 costs.

Maintenance costs were estimated by three different methods depending on aircraft type. Direct maintenance cost information provided by the CPA based on its 1987 membership surveys was used as the basis for estimating the relationship between horsepower and maintenance costs per flight hour for piston engine aircraft. This basic information was also backdated to 1984 using the maintenance cost indices for single-engine and multi-engine piston aircraft published in the FAA Forecasts. The estimation relationships used were:

For 1984, V.O.C., Maintenance = -6.33 + .1189 x Horsepower,
For 1987, V.O.C., Maintenance = -6.77 + .1273 x Horsepower.

The R-squared (R^2) results were .88 and .91 for these relationships. Engine horsepower values appear in the Bluebook.

Direct maintenance costs for turboprop and turbojet/fan aircraft were assigned by analogy to costs reported on Form 298-C by small air carriers operating similar aircraft. Costs for 1984 were estimated from 1985 Form 298-C reports and backdated using the maintenance cost indices for turboprop and turbojet aircraft in the FAA Forecasts.

Direct maintenance costs for rotorcraft were derived from earlier estimates appearing in Economic Values. Piston engine rotorcraft costs were updated using the FAA Forecasts maintenance cost index for fixed wing multi-engine piston aircraft (because of the greater complexity of a single piston engine rotorcraft compared to a fixed wing aircraft). Turbine engine rotorcraft costs were updated using the FAA Forecasts maintenance cost index for turboprop fixed wing aircraft. Because they are not based on any recent direct observations, it is likely that these cost estimates are less accurate than those for fixed wing aircraft.

The variable operating cost estimates used in this study by make/model for 1987 are given in Section 10, Appendix Table 3.

Table 22 presents population weighted general aviation variable operating cost estimates by aircraft type for 1984 and 1987. Table 23 presents general aviation variable operating cost estimates by aircraft type weighted by total hours flown for 1984 and 1987.

Tables 24-A and 24-B give variable operating cost estimates for 1984 and 1987 weighted by general aviation fleet population use profiles. For these tables, the total active fleet by aircraft type was given a relative share of each use profile based on the primary use indicated in the G.A. Survey. Three primary use groups were used: air taxi, commuter and all other (personal, business, aerial application, etc.). These primary use categories

were grouped in various ways to produce six different population weighted estimates of general aviation variable operating costs as described in Section 4.

Tables 25-A and 25-B present variable operating cost estimates for general aviation use profiles for 1984 and 1987 weighted by total hours flown under each profile for air taxi, commuter and all other uses.

In general there have been no dramatic changes in general aviation variable operating costs over the three year time period examined in this study. In terms of overall fleet population, the conventional general aviation fleet has not undergone much change between 1984 and 1986 (the GA Survey year used to produce the 1987 estimates). Thus, the decrease in variable operating costs over time for the first three population-weighted profiles largely reflects major reductions in fuel costs. Cost results for the last three population-weighted profiles reflect changes in the types and models of aircraft used principally for air taxi and air commuter service. Between 1984 and 1986 air taxi service moved to somewhat larger aircraft while air commuter use moved increasingly toward smaller aircraft.

Variable operating costs weighted by hours flown show the clear tendency in general aviation for the steady increase in relative use of larger aircraft. Only the "commuter only" profile goes against this trend, as many aircraft listed in the general aviation fleet in 1984, but indicating the high use of air carrier aircraft, were reported as air carrier aircraft in 1986.

D. Military Aircraft

Weighted variable operating costs for military aircraft were derived from four sources:

1. The Defense Marketing Services 1987 World Military Aircraft Forecast[123] and 1987 World Helicopter Forecast[124] (DMS Forecasts) provided the population forecasts for the aircraft used in this study.
2. Cost Analysis-US Air Force Cost and Planning Factors[125] provided direct operating cost per flight hour information for most aircraft types operated by the Air Force.
3. Cost Per Flying Hour[126] produced by the U.S. Army provided current direct cost per flight hour estimates used by the Army. Most rotorcraft operating cost information came from this publication.
4. O and S Cost Factors[127] produced by the U.S. Navy provided observed historical direct operating costs for five of the most common Navy aircraft models.

Military aircraft production programs and fleet populations are more predictable over time than is the case for civilian aircraft. This fact is used to forecast population-weighted military aircraft variable operating costs (in constant $1988) for the years 1988-1992. No attempt was made to

weight military aircraft types by relative hours of flight as this information is not readily obtainable. Only fuel and oil and direct maintenance costs are included. Crew costs for military crews do not generally vary directly with flight hours.

For the clear majority of military aircraft models, observed variable operating cost data was available from one of the sources listed above. For a small number of aircraft, all of them Navy aircraft, no model specific data was available. In these cases, costs were assigned by analogy using military aircraft types for which costs were available. For example, costs were assigned to the F-18 based on its gross weight relative to the F-14 (for which data was given) because both aircraft are high performance Navy fighters. Section 10, Appendix Table 5 lists variable operating costs in 1988 for the models used.

Aircraft were grouped into six type categories and their projected yearly relative populations were used to estimate population weighted variable operating costs for each type (see Section 10, Appendix Table 9 for yearly populations by model). Weighted variable operating cost estimates for military aircraft are presented in Table 26. All costs are indicated in constant 1988 dollars.

The overall decrease in constant dollar variable operating costs over time as indicated in Table 26, except for rotorcraft, is the result of systematic replacements of older aircraft with newer, more efficient aircraft with reduced maintenance demands. In the case of rotorcraft, the army fleet is in general being replaced by larger aircraft. Consequently, rotorcraft costs show projected constant dollar increases over time.

Table 19

CY 1985 AIR CARRIER VARIABLE OPERATING COSTS BY EQUIPMENT TYPE

Equipment Type	V.O.C. Per Block Hour			Total V.O.C. Per		Activity (Hours)		Dollar Extensions	
	Crew	Fuel & Oil	Maintenance	Block Hour	Airborne Hour	Block	Airborne	Block	Airborne
Turbofan, 4-Engine, Wide Body	$719.04	$2,846.93	$614.65	$4,180.62	$4,619.47	591,158	537,954	$2,471,405,998	$2,485,060,175
Turbofan, 4-Engine, Narrow Body	617.35	1,086.27	210.19	1,913.81	2,114.71	306,708	279,104	$586,981,585	$590,224,577
Turbofan, 3-Engine, Wide Body	674.04	1,870.84	494.54	3,039.42	3,358.47	937,922	853,509	$2,850,737,992	$2,866,487,926
Turbofan, 3-Engine, Narrow Body	490.99	998.18	197.16	1,686.32	1,863.34	3,285,547	2,989,848	$5,540,484,043	$5,571,094,452
Turbofan, 2-Engine, Wide Body	597.77	1,239.18	218.37	2,055.31	2,271.07	362,620	329,984	$745,297,656	$749,415,323
Turbofan, 2-Engine, Narrow Body	320.95	673.97	175.78	1,170.71	1,293.60	3,558,793	3,238,502	$4,166,304,971	$4,189,323,231
Turboprop, 4-Engine	143.87	234.57	228.13	606.57	739.72	253,572	209,197	$153,809,247	$154,747,108
Turboprop, 2-Engine, 20+ Seats	70.89	117.97	84.85	273.72	333.80	989,596	816,417	$270,867,458	$272,519,088
Turboporp, 2-Engine, LT 20 Seats	56.14	86.87	67.34	210.35	256.52	852,148	703,022	$179,249,306	$180,342,290
Piston, Multi-Engine	46.88	48.90	53.20	148.98	181.68	313,738	258,834	$46,740,714	$47,025,719
Turboprop, 2-Engine, ALASKA	102.88	226.43	131.33	460.65	561.76	117,559	96,986	$54,152,923	$54,483,124
Piston, All Types, ALASKA	88.89	124.39	74.89	288.17	351.43	218,021	179,867	$62,827,182	$63,210,275
Weighted Average and Totals:	$374.92	$866.83	$211.40	$1,453.15	$1,641.43	11,787,382	10,493,224	$17,128,859,076	$17,223,933,287

Table 20

CY 1986 AIR CARRIER VARIABLE OPERATING COSTS BY EQUIPMENT TYPE

	V.O.C. Per Block Hour			Total V.O.C. Per		Activity (Hours)		Dollar Extensions	
Equipment Type	Crew	Fuel & Oil	Maintenance	Block Hour	Airborne Hour	Block	Airborne	Block	Airborne
Turbofan, 4-Engine, Wide Body	$765.47	$2,048.96	$690.91	$3,505.34	$4,223.30	669,625	559,137	$2,347,263,822	$2,361,403,966
Turbofan, 4-Engine, Narrow Body	505.71	629.85	333.02	1,468.58	1,769.37	433,859	362,272	$637,155,813	$640,994,101
Turbofan, 3-Engine, Wide Body	632.75	1,322.79	560.18	2,515.73	3,031.00	1,106,587	924,000	$2,783,873,677	$2,800,644,000
Turbofan, 3-Engine, Narrow Body	456.51	712.32	227.19	1,396.02	1,681.95	3,636,207	3,036,233	$5,076,208,865	$5,106,788,436
Turbofan, 2-Engine, Wide Body	551.20	848.49	304.06	1,703.75	2,052.71	468,478	391,179	$798,169,045	$802,977,292
Turbofan, 2-Engine, Narrow Body	328.00	468.11	197.29	993.40	1,196.87	4,390,525	3,666,088	$4,361,562,386	$4,387,836,858
Turboprop, 4-Engine	164.68	179.39	334.55	678.62	827.58	205,920	169,884	$139,740,803	$140,592,881
Turboprop, 2-Engine, 20+ Seats	87.71	93.94	103.60	285.26	347.87	1,001,536	826,267	$285,694,909	$287,436,951
Turboporp, 2-Engine, LT 20 Seats	63.87	70.52	89.07	223.46	272.51	958,428	790,703	$214,170,294	$215,476,210
Piston, Multi-Engine	44.56	44.33	48.32	137.21	167.33	277,091	228,600	$38,019,644	$38,251,471
Turboprop, 2-Engine, ALASKA	98.45	207.99	186.07	492.50	600.61	125,103	103,210	$61,613,193	$61,988,883
Piston, All Types, ALASKA	78.21	105.44	88.71	272.36	332.15	192,554	158,857	$52,444,881	$52,764,667
Weighted Average and Totals:	$372.28	$624.48	$250.52	$1,247.29	$1,506.46	13,465,912	11,216,430	$16,795,917,330	$16,897,155,715

Table 21

ESTIMATED CY 1987 AIR CARRIER VARIABLE OPERATING COSTS BY EQUIPMENT TYPE

Equipment Type	V.O.C. Per Block Hour Crew	V.O.C. Per Block Hour Fuel & Oil	V.O.C. Per Block Hour Maintenance	Total V.O.C. Per Block Hour	Total V.O.C. Per Airborne Hour	Activity (Hours) Block	Activity (Hours) Airborne	Dollar Extensions Block	Dollar Extensions Airborne
Turbofan, 4-Engine, Wide Body	$811.67	$1,875.57	$708.64	$3,395.87	$4,066.91	665,639	559,137	$2,260,424,481	$2,273,959,957
Turbofan, 4-Engine, Narrow Body	498.56	708.16	332.68	1,539.40	1,843.59	431,276	362,272	$663,906,610	$667,882,098
Turbofan, 3-Engine, Wide Body	646.68	1,228.08	615.65	2,490.42	2,982.54	1,100,000	924,000	$2,739,461,061	$2,755,865,019
Turbofan, 3-Engine, Narrow Body	460.51	673.51	221.42	1,355.43	1,623.26	3,614,563	3,036,233	$4,899,269,183	$4,928,606,125
Turbofan, 2-Engine, Wide Body	500.99	808.00	380.31	1,689.30	2,023.12	465,689	391,179	$786,689,926	$791,400,645
Turbofan, 2-Engine, Narrow Body	328.22	438.05	187.29	953.55	1,141.98	4,364,390	3,666,088	$4,161,680,325	$4,186,600,566
Turboprop, 4-Engine	148.79	144.44	387.74	680.97	830.45	205,920	169,884	$140,225,309	$141,080,341
Turboprop, 2-Engine, 20+ Seats	85.93	90.64	116.55	293.13	357.47	1,001,536	826,267	$293,577,973	$295,368,082
Turboporp, 2-Engine, LT 20 Seats	77.82	88.41	97.75	263.98	321.93	958,428	790,703	$253,005,802	$254,548,520
Piston, Multi-Engine	38.13	44.41	46.22	128.76	157.02	277,091	228,600	$35,678,225	$35,895,776
Turboprop, 2-Engine, ALASKA	70.51	145.31	156.52	372.34	454.08	125,103	103,210	$46,581,179	$46,865,210
Piston, All Types, ALASKA	61.78	117.57	96.13	275.48	335.96	192,554	158,857	$53,045,442	$53,368,889
Weighted Average and Totals:	$374.53	$588.39	$255.81	$1,218.72	$1,464.94	13,402,190	11,216,430	$16,333,545,515	$16,431,441,229

Table 22

POPULATION WEIGHTED GENERAL AVIATION AIRCRAFT VARIABLE OPERATING COSTS BY AIRCRAFT TYPE

Aircraft Type	Year	Crew	Fuel & Oil	Maintenance	Total V.O.C. Per Hour	
					Air Taxi/Commuter	Other
Fixed Wing						
(1) Piston, 1-Engine, 1-3 Seats	1984	$40.00	$15.92	$9.63	$65.55	$25.55
	1987	42.00	13.93	10.10	66.03	24.03
(2) Piston, 1-Engine, 4+ Seats	1984	40.00	21.38	19.53	30.91	40.91
	1987	42.00	19.14	21.01	82.15	40.15
(3) Piston, 2-Engine, 1-6 Seats	1984	47.00	54.88	56.89	158.78	111.78
	1987	56.00	49.16	61.23	166.39	110.39
(4) Piston, 2-Engine, 7+ Seats	1984	47.00	64.30	61.89	173.19	126.19
	1987	56.00	57.17	65.83	179.00	123.00
(5) Other Piston*						
(6) Turboprop, 2-Engine, 1-12 Seats	1984	68.00	141.17	92.16	301.33	233.33
	1987	76.00	123.18	98.65	297.83	221.83
(7) Turboprop, 2-Engine, 13+ Seats	1984	68.00	160.64	92.16	320.80	252.80
	1987	76.00	138.85	98.65	313.50	237.50
(8) Other Turboprop*						
(9) Turbojet, 2-Engine	1984	215.00	433.15	190.70	838.85	623.85
	1987	146.00	372.60	203.06	721.66	575.66
(10) Other Turbojet*						
Rotorcraft						
(11) Piston	1984	40.00	26.77	32.78	99.55	59.55
	1987	42.00	24.26	35.01	101.27	59.27
(12) Turbine	1984	47.00	69.21	66.48	182.69	135.69
	1987	56.00	68.12	71.04	139.16	195.16

* Insufficient population to provide reliable estimates.

Table 23

GENERAL AVIATION AIRCRAFT VARIABLE OPERATING COSTS BY AIRCRAFT TYPE, WEIGHTED BY HOURS FLOWN

Aircraft Type	Year	Crew	Fuel & Oil	Maintenance	Total V.O.C. Per Hour: Air Taxi/Commuter	Total V.O.C. Per Hour: Other
Fixed Wing						
(1) Piston, 1-Engine, 1-3 Seats	1984	$40.00	$17.49	$11.43	$68.82	$28.82
	1987	42.00	16.06	12.65	70.71	28.71
(2) Piston, 1-Engine, 4+ Seats	1984	40.00	22.20	20.42	82.62	42.62
	1987	42.00	19.81	21.88	83.69	41.69
(3) Piston, 2-Engine, 1-6 Seats	1984	47.00	58.84	59.85	165.69	118.69
	1987	56 00	51.57	63.17	170.74	114.74
(4) Piston, 2-Engine, 7+ Seats	1984	47.00	63.69	60.98	171.67	124.67
	1987	56.00	57.80	66.34	180.14	124.14
(5) Other Piston*						
(6) Turboprop, 2-Engine, 1-12 Seats	1984	68.00	143.43	92.16	303.59	235.59
	1987	76.00	124.91	98.65	299.56	223.56
(7) Turboprop, 2-Engine, 13+ Seats	1984	68.00	156.75	92.16	316.91	248.91
	1987	76.00	132.73	98.65	3[illegible].39	231.39
(8) Other Turboprop*						
(9) Turbojet, 2-Engine	1984	215.00	431.03	190.70	836.73	621.73
	1987	146.00	375.70	203.06	724.75	578.75
(10) Other Turbojet*						
Rotorcraft						
(11) Piston	1984	40.00	25.74	32.78	98.52	58.52
	1987	42.00	25.00	35.01	102.01	60.01
(12) Turbine	1984	47.00	68.27	66.48	181.75	134.75
	1987	56.00	61.51	71.04	188.56	132.56

* Insufficient population to provide reliable estimates.

Table 24-A

POPULATION WEIGHTED VARIABLE OPERATING COSTS OF GENERAL AVIATION AIRCRAFT PROFILES - 1984

Aircraft Type Category *	V.O.C. Per Hour By Type	G.A. Including Taxi/Comm.		G.A. Excluding Commuter		G.A. Excluding Taxi and Comm.		Air Taxi and Commuter		Air Taxi Only		Commuter Only	
		Relative Active Population	Ext.	Relative Active Population	Ext.	Relative Active Population	Ext.	Relative Active Population	Ext.	Relative Active Population	Ext.	Relative Active Population	Ext.
1-T/C	$65.55	0.0000	$0.00	0.0000	$0.00			0.0000	$0.00	0.0000	$0.00	0.0000	$0.00
1-O	25.55	0.2901	7.41	0.2917	7.45	0.3020	$7.72						
2-T/C	80.91	0.0101	0.82	0.0095	0.77			0.2568	20.78	0.2806	22.70	0.1140	9.22
2-O	40.91	0.5043	20.63	0.5078	20.78	0.5250	21.48						
3-T/C	158.78	0.0069	1.10	0.0061	0.97			0.1755	27.86	0.1799	28.57	0.1489	23.64
3-O	111.78	0.0708	7.91	0.0717	8.02	0.0734	8.20						
4-T/C	173.19	0.0095	1.65	0.0073	1.26			0.2410	41.75	0.2141	37.09	0.4027	69.74
4-O	126.19	0.0313	3.95	0.0338	4.26	0.0326	4.11						
6-T/C	301.33	0.0026	0.77	0.0023	0.71			0.0651	19.61	0.0690	20.78	0.0416	12.53
6-O	233.33	0.0208	4.85	0.0211	4.93	0.0216	5.05						
7-T/C	320.80	0.0016	0.51	0.0001	0.03			0.0407	13.07	0.0024	0.76	0.2712	87.00
7-O	252.80	0.0014	0.35	0.0029	0.74	0.0014	0.37						
9-T/C	838.85	0.0016	1.37	0.0015	1.30			0.0416	34.86	0.0456	38.22	0.0175	14.65
9-O	623.85	0.0161	10.01	0.0162	10.13	0.0167	10.42						
11-T/C	99.55	0.0001	0.01	0.0002	0.01			0.0038	0.38	0.0044	0.44	0.0000	0.00
11-O	59.55	0.0136	0.81	0.0137	0.81	0.0141	0.84						
12-T/C	182.69	0.0069	1.26	0.0069	1.26			0.1755	32.06	0.2037	37.22	0.0058	1.06
12-O	135.69	0.0126	1.70	0.0127	1.72	0.0131	1.77						
Total:			$65.14		$65.16		$59.97		$190.36		$185.78		$217.86

* "T/C" represents costs for taxi and commuter uses, "O" represents costs for all other uses.

Table 24-B

POPULATION WEIGHTED VARIABLE OPERATING COSTS OF GENERAL AVIATION AIRCRAFT PROFILES - 1987

Aircraft Type Category *	V.O.C. Per Hour By Type	G.A. Including Taxi/Comm.		G.A. Excluding Commuter		G.A. Excluding Taxi and Comm.		Air Taxi and Commuter		Air Taxi Only		Commuter Only	
		Relative Active Population	Ext.	Relative Active Population	Ext.	Relative Active Population	Ext.	Relative Active Population	Ext.	Relative Active Population	Ext.	Relative Active Population	Ext.
1-T/C	$66.03	0.0018	$0.12	0.0018	$0.12			0.0421	$2.78	0.0513	$3.39	0.0000	$0.00
1-O	24.03	0.2923	7.02	0.2946	7.08	0.3056	$7.34						
2-T/C	82.15	0.0104	0.86	0.0087	0.71			0.2403	19.74	0.2414	19.83	0.2353	19.33
2-O	40.15	0.5047	20.26	0.5087	20.42	0.5277	21.18						
3-T/C	166.39	0.0062	1.03	0.0059	0.98			0.1420	23.62	0.1647	27.40	0.0381	6.34
3-O	110.39	0.0700	7.73	0.0705	7.79	0.0732	8.08						
4-T/C	179.00	0.0097	1.73	0.0080	1.43			0.2225	39.82	0.2225	39.83	0.2220	39.74
4-O	123.00	0.0259	3.19	0.0261	3.21	0.0271	3.33						
6-T/C	297.83	0.0028	0.85	0.0021	0.64			0.0654	19.48	0.0596	17.75	0.0920	27.39
6-O	221.83	0.0198	4.40	0.0200	4.43	0.0207	4.60						
7-T/C	313.50	0.0031	0.97	0.0004	0.12			0.0716	22.44	0.0104	3.27	0.3515	110.19
7-O	237.50	0.0015	0.35	0.0015	0.35	0.0015	0.36						
9-T/C	721.66	0.0024	1.74	0.0024	1.75			0.0556	40.15	0.0674	48.64	0.0018	1.31
9-O	575.66	0.0166	9.56	0.0167	9.63	0.0174	9.99						
11-T/C	101.27	0.0002	0.02	0.0002	0.02			0.0043	0.44	0.0048	0.48	0.0024	0.25
11-O	59.27	0.0136	0.80	0.0137	0.81	0.0142	0.84						
12-T/C	195.16	0.0068	1.32	0.0064	1.25			0.1560	30.44	0.1777	34.69	0.0563	10.98
12-O	139.16	0.0122	1.69	0.0123	1.71	0.0127	1.77						
Total:			$63.64		$62.45		$57.50		$198.91		$195.28		$215.52

* See Table 24-A

Table 25-A

VARIABLE OPERATING COSTS OF GENERAL AVIATION AIRCRAFT PROFILES, WEIGHTED BY HOURS FLOWN - 1984

Aircraft Type Category *	V.O.C. Per Hour By Type	G.A. Including Taxi/Comm.		G.A. Excluding Commuter		G.A. Excluding Taxi and Comm.		Air Taxi and Commuter		Air Taxi Only		Commuter Only	
		Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.	Relative Hours Flown	Ext.
1-T/C	$68.82	0.0000	$0.00	0.0000	$0.00			0.0000	$0.00	0.0000	$0.00	0.0000	$0.00
1-O	28.82	0.2428	7.00	0.2529	7.29	0.2770	$7.98						
2-T/C	82.62	0.0203	1.68	0.0185	1.53			0.1642	13.56	0.2127	17.57	0.0621	5.13
2-O	42.62	0.4016	17.12	0.4182	17.83	0.4582	19.53						
3-T/C	165.69	0.0164	2.72	0.0134	2.22			0.1327	21.99	0.1534	25.42	0.0892	14.78
3-O	118.69	0.0680	8.07	0.0708	8.40	0.0776	9.21						
4-T/C	171.67	0.0337	5.79	0.0208	3.57			0.2728	46.84	0.2384	40.93	0.3452	59.26
4-O	124.67	0.0398	4.96	0.0415	5.17	0.0454	5.66						
6-T/C	303.59	0.0061	1.86	0.0051	1.54			0.0496	15.04	0.0583	17.70	0.0312	9.46
6-O	235.59	0.0424	9.98	0.0441	10.40	0.0483	11.39						
7-T/C	316.91	0.0170	5.38	0.0003	0.10			0.1373	43.52	0.0036	1.15	0.4184	132.58
7-O	248.91	0.0039	0.96	0.0040	1.00	0.0044	1.10						
9-T/C	836.73	0.0048	3.99	0.0030	2.48			0.0386	32.26	0.0340	28.41	0.0482	40.33
9-O	621.73	0.0328	20.39	0.0342	21.24	0.0374	23.27						
11-T/C	98.52	0.0004	0.04	0.0004	0.04			0.0032	0.31	0.0047	0.46	0.0000	0.00
11-O	58.52	0.0163	0.96	0.0170	1.00	0.0187	1.09						
12-T/C	181.75	0.0249	4.53	0.0257	4.67			0.2017	36.66	0.2949	53.60	0.0058	1.05
12-O	134.75	0.0289	3.89	0.0301	4.06	0.0330	4.44						
Total:			$99.30		$92.53		$83.67		$210.18		$185.24		$262.59

* See Table 24-A

Table 25-B

VARIABLE OPERATING COSTS OF GENERAL AVIATION AIRCRAFT PROFILES, WEIGHTED BY HOURS FLOWN - 1987

Aircraft Type Category *	V.O.C. Per Hour By Type	G.A. Including Taxi/Comm. Relative Hours Flown	G.A. Including Taxi/Comm. Ext.	G.A. Excluding Commuter Relative Hours Flown	G.A. Excluding Commuter Ext.	G.A. Excluding Taxi and Comm. Relative Hours Flown	G.A. Excluding Taxi and Comm. Ext.	Air Taxi and Commuter Relative Hours Flown	Air Taxi and Commuter Ext.	Air Taxi Only Relative Hours Flown	Air Taxi Only Ext.	Commuter Only Relative Hours Flown	Commuter Only Ext.
1-T/C	$70.71	0.0023	$0.16	0.0024	$0.17			0.0153	$1.08	0.0265	$1.88	0.0000	$0.00
1-O	28.71	0.2290	6.58	0.2445	7.02	0.2692	$7.73						
2-T/C	83.69	0.0274	2.29	0.0199	1.67			0.1832	15.34	0.2168	18.14	0.1376	11.52
2-O	41.69	0.3897	16.25	0.4160	17.34	0.4581	19.10						
3-T/C	170.74	0.0142	2 42	0.0138	2.36			0.0948	16.18	0.1504	25.67	0.0191	3.26
3-O	114.74	0.0685	7.86	0.0732	8.40	0.0806	9.24						
4-T/C	180.14	0.0278	5.01	0.0177	3.19			0.1861	33.52	0.1927	34.71	0.1770	31.89
4-O	124.14	0.0347	4.30	0.0370	4.59	0.0407	5.06						
6-T/C	299.56	0.0132	3.96	0 0055	1.64			0.0886	26.55	0.0596	17.84	0.1282	38.40
6-O	223.56	0.0355	7.93	0.0379	8.46	0.0417	9.32						
7-T/C	307.39	0.0310	9.52	0.0009	0.29			0.2074	63.77	0.0103	3.15	0.4758	146.24
7-O	231.39	0.0030	0.69	0.0032	0.74	0.0035	0.81						
9-T/C	724.75	0.0093	6.70	0.0063	4.54			0 0393	28.50	0.0681	49.36	0.0002	0.13
9-O	578.75	0.0370	21.44	0.0431	24.97	0.0475	27.50						
11-T/C	102.01	0.0005	0.05	0.0005	0.05			0.0031	0.31	0.0049	0.50	0.0006	0.06
11-O	60.01	0.0233	1.40	0.0249	1.49	0.0274	1.64						
12-T/C	188.56	0.0272	5.13	0.0249	4.69			0.1822	34.35	0.2708	51.06	0.0615	11.60
12-O	132.56	0.0266	3.53	0.0284	3.77	0.0313	4.15						
Total:			$105.21		$95.37		$84.55		$219.60		$202.32		$243.10

* See Table 24-A

Table 26

MILITARY AIRCRAFT VARIABLE OPERATING COSTS 1988-92
(all costs constant 1988 dollars)

Aircraft Type	Year	Fuel & Oil	Maintenance	Total	Relative Population
Turbojet/fan - Multi-Engine	1988	$1,806	$723	$2,529	0.0656
	1989	1,798	720	2,518	0.0653
	1990	1,787	716	2,503	0.0649
	1991	1,775	711	2,486	0.0646
	1992	1,763	707	2,470	0.0639
Turbojet/fan - Attack/Fighter	1988	$955	$1,063	$2,018	0.3084
	1989	925	1,060	1,985	0.3112
	1990	900	1,060	1,960	0.3143
	1991	880	1,057	1,937	0.3191
	1992	867	1,051	1,918	0.3237
Turbojet/fan - Other	1988	$248	$261	$510	0.1027
	1989	248	259	508	0.0990
	1990	248	259	507	0.0960
	1991	248	258	506	0.0925
	1992	248	257	505	0.0891
Turboprop	1988	$330	$425	$756	0.1038
	1989	327	427	754	0.1028
	1990	325	428	753	0.1015
	1991	323	427	749	0.0998
	1992	319	425	744	0.0977
Piston Engine	1988	$24	$49	$73	0.0088
	1989	24	49	73	0.0085
	1990	24	50	74	0.0082
	1991	24	50	74	0.0079
	1992	24	50	75	0.0077
Rotary Wing	1988	$74	$238	$312	0.4108
	1989	74	245	319	0.4132
	1990	76	252	328	0.4150
	1991	77	259	336	0.4160
	1992	78	266	344	0.4179
Weighted Average[a]	1988	$504	$545	$1,049	
	1989	495	549	1,044	
	1990	488	554	1,042	
	1991	483	559	1,042	
	1992	480	562	1,042	

[a]Weighted by relative projected populations

SECTION 6: UNIT REPLACEMENT AND RESTORATION COSTS OF DAMAGED AIRCRAFT

A. Introduction

The costs of damage to aircraft in aviation accidents are borne directly by operators and indirectly by users and society in the form of higher fares and taxes. Determining these costs provides a measure for the evaluation of FAA investment and regulatory programs which affect the likelihood of aircraft being damaged or destroyed.

The National Transportation Safety Board (NTSB) classifies aircraft involved in accidents as "destroyed," having "substantial damage," having "minor damage," or having "no damage." In this section, a destroyed aircraft will be assigned the value of an identical or nearly identical replacement aircraft. The "replacement cost" used here for an aircraft will be the cost of replacing a destroyed aircraft from the used aircraft market. Because used aircraft prices already incorporate depreciation and obsolescence factors, these elements do not need to be considered separately. The special case of military aircraft will be discussed in part D of this section.

Current insurance experience reveals that the average restoration cost (as a percentage of aircraft replacement cost) for substantially damaged aircraft varies markedly by aircraft type. Of the aviation insurance and claims adjustment sources contacted for this study, Loss Management Services, Inc.[128] provided by far the most complete and consistent information. It examined 1,113 claims for damage exceeding $5,000 over the period 1/1/86 to 3/1/88. Total losses and aircraft valued at less than $8,000 were excluded from this study. Only fixed wing aircraft were included. Table 27 presents the values used in this study for the restoration cost of a substantially damaged aircraft as a percent of the aircraft's market value. The information provided by Loss Management Services has been adjusted to conform to FAA-APO type classifications. There is an insufficient population of other fixed wing piston, other turboprop, and other turbojet (general aviation types 5, 8 and 10) aircraft to obtain a meaningful estimate of restoration costs. These types have also been excluded from the weighted replacement cost estimates because of insignificant populations. Restoration cost percentages have been assigned to the two rotorcraft types by analogy.

The sources contacted for this study indicated that the repair costs of aircraft incurring minor damage was generally a negligible percentage of their market value. It is also the experience of the industry that minor damage frequently results from factors beyond the purview of the FAA (for example, weather damage while parked on the ground).

The replacement and restoration costs presented in this section are weighted by the estimated relative aircraft type populations or where appropriate, by the relative utilization comprising the respective aircraft fleets. Derived costs are not weighted by relative accident exposure.

Table 27

Restoration Cost of Damaged Aircraft as a Percent of Aircraft Replacement Cost

Aircraft Type	Restoration Cost as % of Replacement Cost
Fixed Wing:	
Air Carrier Aircraft	13%
General Aviation Aircraft	
Piston, 1-Engine, 1-3 Seats	29%
Piston, 1-Engine, 4+ Seats	29%
Piston, 2-Engine, 1-6 Seats	24%
Piston, 2-Engine, 7+ Seats	24%
Turboprop, 2-Engine, 1-12 Seats	13%
Turboprop, 2-Engine, 13+ Seats	13%
Turbojet/fan, 2-Engine	13%
Rotorcraft:	
Piston	29%
Turbine	13%

B. Accident Investigation Costs

The cost of accident investigation should be added to any calculation of the cost of statistical aviation accidents on a per-accident basis. Hoffer[129] still provides the best estimate of accident investigation costs. These costs, listed below, have been updated to 1987 dollars using the GNP Implicit Price Deflator.

1. Air Carrier Accidents

NTSB Major Accidents:	$1,000,000 per accident
NTSB Regular Investigations:	$ 12,370 per accident
Weighted Air Carrier Average:	$ 349,000 per accident

2. General Aviation and Air Taxi Accidents

NTSB Regular Investigations:	$ 12,370 per accident
FAA Regular Investigations:	$ 3,160 per accident
Weighted GA and Air Taxi Average:	$ 5,000 per accident

C. Air Carrier Aircraft

The weighted unit replacement costs of air carrier aircraft were derived from two sources:

1. Avmark Newsletter[130] (Avmark), contains semi-annual summaries of the market value of all sub-models of air carrier turbojet/fan (a Boeing 737-200 will be considered a sub-model of the Boeing 737) and most models of turboprop aircraft and records ownership transfer of used aircraft and deliveries of new aircraft. Includes estimate of active world fleet by sub-model.
2. Census of U.S. Civil Aircraft[131] (Census), gives yearly fleet population by sub-model.

The Avmark Newsletter was used to obtain semi-annual estimates of the average value of sub-models of aircraft used by U.S. air carriers for the period 1984-1987. After calculating a yearly average value by sub-model, yearly population counts for 1984-1986 by sub-model provided by the Census were used to calculate a population-weighted average replacement cost by FAA-APO type classification. The 13% restoration cost factor was applied to average replacement costs to obtain average restoration cost by aircraft type. Weighting by utilization within a type classification is not required because most models within a type classification have similar utilization characteristics.

Aircraft fleet estimates for 1987 were obtained by examining the monthly listings of aircraft transactions reported in Avmark to obtain a net change in the fleet by sub-model since the 1986 Census estimates. Replacement and restoration cost estimates were not made prior to 1984 because Avmark did not report average turboprop values prior to that time.

Section 10, Appendix Table 6 provides a full listing of all aircraft sub-models used in this analysis for 1987 with their respective fleet size, average values, total values, and weighted replacement costs by FAA-APO type. Table 28 summarizes weighted air carrier replacement and restoration cost values for the period 1984-1987 by FAA-APO type and for the entire fleet.

It is clear that replacement costs by type show no uniform trends over time. Technological innovation and changing route demands can produce rapid changes in replacement costs. For example, 4-engine regular body aircraft have shown dramatic price increases due to the introduction of hush-kits for the DC-8 and expanding fleet of BAE 146's while changing route needs have caused 4-engine wide body values to go up and down during the same time period.

D. General Aviation Aircraft

The general aviation fleet is composed of a highly diverse population of aircraft. For the purpose of making regulatory and investment decisions, it will be appropriate in some occasions to use a population count weight to estimate replacement and restoration costs. At other times a utilization

weight should be used. The weights used to calculate type and total fleet average costs were determined at the make/model level (for example, depending on the weighting method required, population or yearly flight hours for the Cessna 172 would be used).

The weighted unit replacement costs of general aviation aircraft were derived from two sources:

1. The Aircraft Bluebook - Price Digest[132] (Bluebook) provides average retail price, overhaul cost, capacity and performance information by aircraft model year for most of the active aircraft make/models in the U.S. general aviation fleet.
2. The General Aviation Activity and Avionics Survey[133] (G.A. Survey) consists of a random sample yearly survey of the registered general aviation population. The raw survey data used in this study included: identification of active aircraft, population count by make/model, year of manufacture, and population count distribution by make/model. The summary information appearing in the survey publication used in this study included: active population by make/model, primary use by type, total hours of flight for all active aircraft for each make/model considered, and total hours of flight by use category by FAA type classification.

The first step in estimating general aviation replacement costs was to determine the average value of representative aircraft in the general aviation fleet. The market value of approximately 110 different make/models by year of manufacture was weighted by the distribution of years of manufacture for each make/model. This was done for the general aviation fleet of 1984 and 1987. For 1987, market values were from the winter 1987/88 Bluebook. Fleet size, model year distribution, and utilization estimates were from the 1986 G.A. Survey. Appendix Table 8 in Section 10 lists the make/models used in the 1987 estimates with their average market values, active fleet size and total flight hours.

Weighted replacement costs by type were calculated by weighting average market values by aircraft make/model/type by either the make/model's relative active fleet within each type or the make/model's relative total flight hours. The population-weighted replacement -t estimates would be applicable to the evaluation of actions not .fected by relative use. It is likely that the use-weighted estimates will have more general application. Restoration cost estimates were developed from the replacement cost estimates using the values presented in Table 27.

Table 29 presents weighted general aviation replacement and restoration cost estimates by aircraft type for 1984 and 1987. Tables 30-A and 30-B present replacement and restoration cost estimates for 1984 and 1987 weighted by fleet population use profiles. For these tables, the total active fleet by make/model was given a relative share of each use profile based on the primary use indicated in the G.A. Survey. Three primary use groups were used: air taxi, commuter and all other (personal, business, aerial application, etc.). For example, the G.A. Survey indicates that of the total active fleet of Cessna 207's in 1984: 203 had primarily air taxi use, 53 had primarily commuter use and 121 had other primary uses. These primary use

categories were grouped in various ways as described in Section 4 to produce six different population weighted estimates of general aviation replacement and restoration costs.

Tables 31-A and 31-B present replacement and restoration cost estimates for 1984 and 1987 weighted by fleet total hours, rather than fleet population, in air taxi, commuter and other uses. For example, the G.A. Survey indicates that the active fleet of Cessna 207's in 1984 had 155,815 hours of use in air taxi service, 50,247 hours commuter service and 20,299 hours in other uses. These estimates of hours, rather than estimates of fleet population by primary use, were used as the weights in Tables 31-A and 31-B.

General aviation replacement costs show changes over time which reflect a variety of factors. Most of the population-weighted estimates validate observations made elsewhere about the current general aviation market.[134] Few type 1, or 2 aircraft are currently being manufactured. As a result, market values for these aircraft have shown stability or slight increases, even though the average age of these aircraft continues to increase. There is also little manufacturing of type 3 and 4 aircraft, but these aircraft have in general lost value, probably due to their higher operating costs.[135]

The flight hours weighted estimates show a somewhat different story. In general, use is moving toward larger, higher valued aircraft. The "commuter only" grouping shows the major changes in the type of aircraft (and the operators) appearing under this grouping in 1987 as compared to 1984. Such changes have likely ended as the major air carrier commuters no longer file as general aviation.

E. Military Aircraft

The weighted unit replacement costs of military aircraft were derived from three sources:

1. The Defense Marketing Services 1987 World Military Aircraft Forecast[136] and 1987 World Helicopter Forecast[137] (DMS Forecasts) provided the population forecasts for the aircraft used in this study, and the current sale price of aircraft in production.

2. Aviation Week and Space Technology[138] publishes yearly budget allocations for military aircraft production and upgrade programs.

3. Jane's All the World's Aircraft[139] provided historical information about aircraft production histories and upgrade programs.

Military aircraft production programs and fleet populations are more predictable over time than is the case for civilian aircraft. This fact is being used to forecast population-weighted military aircraft replacement and restoration costs (in constant $1988) for the years 1988-1992. No attempt was made to weight military aircraft by relative hours of flight since this information is not readily obtainable.

Civilian aircraft replacement costs ultimately indicate the market value of the stream of services over time offered by an aircraft. The military replacement costs given here estimate the value to the government of the stream of services offered by military aircraft. Four criteria were used in calculating the average value of each of the 70 military aircraft used in these estimates. These criteria are listed below in descending order of preference (each method was examined in order until one was found to be applicable):

1. If an aircraft is currently in production its current production cost will be taken as its replacement cost. Depreciation is not clearly indicated for these aircraft because existing recently produced aircraft are generally upgraded over time to be equivalent or nearly equivalent to new production aircraft, and will therefore have similar service value.

2. If an aircraft not in production has a civilian equivalent or there is a civilian aircraft with similar performance and age characteristics, the average civilian market value of the comparable aircraft is used. For example the Lockheed L-100 is the civilian version of the C-130.

3. If an aircraft is not in production and has no clear civilian equivalent the per-unit cost of recent major upgrades was used as its current service value. For example the Boeing B-52 has been out of production for 25 years, but remaining fleet aircraft have had significant and costly upgrades in recent years.

4. If all of the prior three treatments failed to apply, a very general value comparison was made between the military aircraft and a generic civilian aircraft. For example, the production cost of an A-7 aircraft built 15 years ago was adjusted by analogy to the original average purchase price compared to the current average market value of a jet transport built 15 years ago and still in service.

Aircraft were grouped into six type categories and their yearly relative populations were used to estimate weighted costs for each type. Weighted replacement and restoration cost estimates for military aircraft are presented in Table 32. Restoration costs are calculated at 13% of replacement costs as recommended for air carrier aircraft and discussed in part A of this section. All costs are indicated in constant 1988 dollars. The overall increase in costs over time as indicated in Table 32 is the result of systematic replacements of older aircraft rather than the application of any price index.

Table 28

AIR CARRIER AIRCRAFT REPLACEMENT AND RESTORATION COSTS 1984-87

Equipment Group	Replacement Cost ($000)				Restoration Cost ($000) (1)			
	1984	1985	1986	1987	1984	1985	1986	1987
Turbofan, 2-Engine, Regular Body	$7,684	$9,764	$9,981	$11,176	$999	$1,269	$1,298	$1,453
Turbofan, 3-Engine, Regular Body	5,421	5,680	5,661	5,372	705	738	736	698
Turbofan, 4-Engine, Regular Body	3,067	9,252	10,428	10,619	399	1,203	1,356	1,380
Turbofan, 2-Engine, Wide Body	33,648	36,651	32,509	32,897	4,374	4,765	4,226	4,277
Turbofan, 3-Engine, Wide Body	14,337	18,845	19,372	20,160	1,864	2,450	2,518	2,621
Turbofan, 4-Engine, Wide Body	22,272	24,308	23,254	23,196	2,895	3,160	3,023	3,015
Turboprop, Multi-Engine, 20+ Seat	1,444	1,449	1,653	1,701	188	188	215	221
Turboprop, Multi-Engine, Other	1,171	1,262	1,352	1,367	152	164	176	178
Weighted Average (2) (By Population)	7,030	8,508	8,427	8,871	914	1,106	1,096	1,153

1 Restoration costs estimated to average 13% of aircraft market value for repairable aircraft with substantial damage.

2 Weighted by the following relative population in order of their presentation above:

1984:	0.2787	0.3052	0.0507	0.0239	0.0728	0.0410	0.1540	0.0736
1985:	0.3013	0.2908	0.0416	0.0265	0.0713	0.0367	0.1468	0.0849
1986:	0.3132	0.2687	0.0394	0.0294	0.0674	0.0344	0.1557	0.0917
1987:	0.3299	0.2618	0.0385	0.0267	0.0654	0.0340	0.1512	0.0925

Table 29

GENERAL AVIATION AIRCRAFT REPLACEMENT AND RESTORATION COSTS BY AIRCRAFT TYPE
(all costs $000)

Aircraft Type	Weighted by Population				Weighted by Hours Flown			
	Replacement Cost		Restoration Cost*		Replacement Cost		Restoration Cost*	
	1984	1987	1984	1987	1984	1987	1984	1987
Fixed Wing								
(1) Piston, 1-Engine, 1-3 Seats	$11.60	$13.60	$3.37	$3.94	$12.35	$14.93	$3.58	$4.33
(2) Piston, 1-Engine, 4+ Seats	23.48	25.79	6.81	7.48	24.83	27.18	7.20	7.88
(3) Piston, 2-Engine, 1-6 Seats	71.04	61.15	17.05	14.68	83.20	65.80	19.97	15.79
(4) Piston, 2-Engine, 7+ Seats	104.62	87.83	25.11	21.08	108.48	97.68	26.04	23.44
(5) Other Piston								
(6) Turboprop, 2-Engine, 1-12 Seats	592.89	517.49	77.08	67.27	641.65	547.03	83.41	71.11
(7) Turboprop, 2-Engine, 13+ Seats	863.69	623.57	112.28	81.06	971.25	663.52	126.26	86.26
(8) Other Turboprop								
(9) Turbojet, 2-Engine	1414.27	1434.24	183.86	186.45	1459.50	1514.33	189.73	196.86
(10) Other Turbojet								
Rotorcraft								
(11) Piston	46.93	46.79	13.61	13.57	48.34	45.86	14.02	13.30
(12) Turbine	322.88	362.81	41.97	47.17	310.87	359.33	40.41	46.71

* Restoration cost factors by type are presented in Table 27.

Table 30-A

POPULATION WEIGHTED REPLACEMENT AND RESTORATION COSTS OF GENERAL AVIATION AIRCRAFT PROFILES - 1984
(all costs $000)

Aircraft Type Category	Replacement Cost	G.A. Including Taxi/Comm.		G.A. Excluding Commuter		G.A. Excluding Taxi and Comm.		Air Taxi and Commuter		Air Taxi Only		Commuter Only	
		Relative Active Population	Ext.	Relative Active Population	Ext.	Relative Active Population	Ext.	Relative Active Population	Ext.	Relative Active Population	Ext.	Relative Active Population	Ext.
1	$11.60	0.2901	$3.37	0.2917	$3.39	0.3020	$3.50	0.0000	$0.00	0.0000	$0.00	0.0000	$0.00
2	23.48	0.5144	12.08	0.5174	12.15	0.5250	12.33	0.2568	6.03	0.2806	6.59	0.1140	2.68
3	71.04	0.0777	5.52	0.0778	5.53	0.0734	5.21	0.1755	12.47	0.1799	12.78	0.1489	10.58
4	104.62	0.0408	4.27	0.0410	4.29	0.0326	3.41	0.2410	25.22	0.2141	22.40	0.4027	42.13
6	592.89	0.0234	13.85	0.0235	13.93	0.0216	12.84	0.0651	38.58	0.0690	40.89	0.0416	24.66
7	863.69	0.0030	2.59	0.0030	2.60	0.0014	1.25	0.0407	35.18	0.0024	2.03	0.2712	234.24
9	1414.27	0.0177	25.02	0.0178	25.16	0.0167	23.63	0.0416	58.77	0.0456	64.45	0.0175	24.71
11	46.93	0.0137	0.64	0.0138	0.65	0.0141	0.66	0.0038	0.18	0.0044	0.21	0.0000	0.00
12	322.88	0.0195	6.29	0.0196	6.32	0.0131	4.22	0.1755	56.66	0.2037	65.78	0.0058	1.88
Replacement Cost:			$73.81		$74.01		$67.05		$233.08		$215.14		$340.87
Restoration Cost (see Table 27):			$13.22		$13.29		$12.30		$35.44		$32.93		$50.54

Table 30-B

POPULATION WEIGHTED REPLACEMENT AND RESTORATION COSTS OF GENERAL AVIATION AIRCRAFT PROFILES - 1987
(all costs $000)

		G.A. Including Taxi/Comm.		G.A. Excluding Commuter		G.A. Excluding Taxi and Comm.		Air Taxi and Commuter		Air Taxi Only		Commuter Only	
Aircraft Type Category	Replacement Cost	Relative Active Population	Ext.	Relative Active Population	Ext.	Relative Active Population	Ext.	Relative Active Population	Ext.	Relative Active Population	Ext.	Relative Active Population	Ext.
1	$13.60	0.2941	$4.00	0.2964	$4.03	0.3056	$4.16	0.0421	$0.57	0.0513	$0.70	0.0000	$0.00
2	25.79	0.5152	13.29	0.5174	13.34	0.5277	13.61	0.2403	6.20	0.2414	6.23	0.2353	6.07
3	61.15	0.0762	4.66	0.0765	4.68	0.0732	4.47	0.1420	8.68	0.1647	10.07	0.0381	2.33
4	87.83	0.0356	3.13	0.0341	3.00	0.0271	2.38	0.2225	19.54	0.2225	19.55	0.2220	19.50
6	517.49	0.0227	11.72	0.0221	11.44	0.0207	10.72	0.0654	33.84	0.0596	30.84	0.0920	47.58
7	623.57	0.0046	2.85	0.0018	1.15	0.0015	0.95	0.0716	44.64	0.0104	6.51	0.3515	219.17
9	1434.24	0.0190	27.28	0.0192	27.47	0.0174	24.89	0.0556	79.80	0.0674	96.66	0.0018	2.60
11	46.79	0.0138	0.64	0.0139	0.65	0.0142	0.66	0.0043	0.20	0.0048	0.22	0.0024	0.11
12	362.81	0.0189	6.87	0.0187	6.77	0.0127	4.62	0.1560	56.59	0.1777	64.49	0.0563	20.41
Replacement Cost:			$74.44		$72.53		$66.47		$250.06		$235.27		$317.77
Restoration Cost (see Table 27):			$13.40		$13.16		$12.34		$38.73		$34.99		$44.70

Table 31-A

REPLACEMENT AND RESTORATION COSTS OF GENERAL AVIATION AIRCRAFT PROFILES, WEIGHTED BY HOURS FLOWN - 1984
(all costs $000)

Aircraft Type Category	Replacement Cost	G.A. Including Taxi/Comm. Relative Hours Flown	G.A. Including Taxi/Comm. Ext.	G.A. Excluding Commuter Relative Hours Flown	G.A. Excluding Commuter Ext.	G.A. Excluding Taxi and Comm. Relative Hours Flown	G.A. Excluding Taxi and Comm. Ext.	Air Taxi and Commuter Relative Hours Flown	Air Taxi and Commuter Ext.	Air Taxi Only Relative Hours Flown	Air Taxi Only Ext.	Commuter Only Relative Hours Flown	Commuter Only Ext.
1	$12.35	0.2428	$3.00	0.2529	$3.12	0.2770	$3.42	0.0000	$0.00	0.0000	$0.00	0.0000	$0.00
2	24.83	0.4219	10.47	0.4368	10.84	0.4582	11.38	0.1642	4.08	0.2127	5.28	0.0621	1.54
3	83.20	0.0844	7.02	0.0842	7.00	0.0776	6.45	0.1327	11.04	0.1534	12.76	0.0892	7.42
4	108.48	0.0735	7.98	0.0623	6.75	0.0454	4.93	0.2728	29.60	0.2384	25.86	0.3452	37.45
6	641.65	0.0485	31.12	0.0492	31.58	0.0483	31.02	0.0496	31.79	0.0583	37.40	0.0312	19.99
7	971.25	0.0208	20.23	0.0043	4.22	0.0044	4.27	0.1373	133.37	0.0036	3.52	0.4184	406.32
9	1459.50	0.0376	54.82	0.0371	54 18	0.0374	54.63	0.0386	56.26	0.0340	49.55	0.0482	70.35
11	48.34	0.0167	0.81	0.0174	0.84	0.0187	0.90	0.0032	0.15	0.0047	0.23	0.0000	0.00
12	310.87	0.0538	16.73	0.0558	17.35	0.0330	10.25	0.2017	62.70	0.2949	91.68	0.0058	1.79
Replacement Cost:			$152.18		$135.89		$127.25		$329.00		$226.29		$544.87
Restoration Cost (see Table 27):			$23.72		$21.55		$20.31		$47.92		$34.55		$76.02

Table 31-B

REPLACEMENT AND RESTORATION COSTS OF GENERAL AVIATION AIRCRAFT PROFILES, WEIGHTED BY HOURS FLOWN - 1987

Aircraft Type Category	Replacement Cost	G.A. Including Taxi/Comm. Relative Hours Flown	G.A. Including Taxi/Comm. Ext.	G.A. Excluding Commuter Relative Hours Flown	G.A. Excluding Commuter Ext.	G.A. Excluding Taxi and Comm. Relative Hours Flown	G.A. Excluding Taxi and Comm. Ext.	Air Taxi and Commuter Relative Hours Flown	Air Taxi and Commuter Ext.	Air Taxi Only Relative Hours Flown	Air Taxi Only Ext.	Commuter Only Relative Hours Flown	Commuter Only Ext.
1	$14.93	0.2313	$3.45	0.2469	$3.69	0.2692	$4.02	0.0153	$0.23	0.0265	$0.40	0.0000	$0.00
2	27.18	0.4171	11.34	0.4359	11.85	0.4581	12.45	0.1832	4.98	0.2158	5.89	0.1376	3.74
3	65.80	0.0827	5.44	0.0870	5.72	0.0806	5.30	0.0948	6.24	0.1504	9.89	0.0191	1.26
4	97.68	0.0625	6.10	0.0547	5.34	0.0407	3.98	0.1861	18.18	0.1927	18.82	0.1770	17.29
6	547.03	0.0487	26.64	0.0433	23.70	0.0417	22.81	0.0886	48.48	0.0596	32.59	0.1282	70.12
7	663.52	0.0340	22.53	0.0041	2.73	0.0035	2.32	0.2074	137.64	0.0103	6.81	0.4758	315.67
9	1514.33	0.0463	70.10	0.0494	74.81	0.0475	71.95	0.0393	59.56	0.0681	103.13	0.0002	0.27
11	45.86	0.0238	1.09	0.0253	1.16	0.0274	1.26	0.0031	0.14	0.0049	0.23	0.0006	0.03
12	359.33	0.0538	19.34	0.0533	19.15	0.0313	11.24	0.1822	65.46	0.2708	97.31	0.0615	22.10
Replacement Cost:			$166.03		$148.16		$135.32		$340.90		$275.06		$430.48
Restoration Cost (see Table 27):			$25.39		$23.15		$21.45		$47.86		$39.96		$58.61

Table 32

MILITARY AIRCRAFT REPLACEMENT AND RESTORATION COSTS 1988-92
(all costs constant $000, 1988)

Aircraft Type	Replacement Cost					Restoration Cost (1)				
	1988	1989	1990	1991	1992	1988	1989	1990	1991	1992
Turbojet/fan - Multi-Engine	$27,349	$28,392	$29,322	$30,154	$31,184	$3,555	$3,691	$3,812	$3,920	$4,054
Turbojet/fan - Attack/Fighter	13,111	13,927	14,683	15,179	15,549	1,704	1,811	1,909	1,973	2,021
Turbojet/fan - Other	2,620	2,653	2,687	2,734	2,792	341	345	349	355	363
Turboprop	12,108	12,357	12,492	12,528	12,577	1,574	1,606	1,624	1,629	1,635
Piston Engine	65	65	65	65	65	8	8	8	8	8
Rotory	2,405	2,566	2,717	2,862	3,003	313	334	353	372	390
Weighted Average (2)	$8,352	$8,782	$9,172	$9,487	$9,760	$1,086	$1,142	$1,192	$1,233	$1,269

1 Restoration costs are taken as 13% of replacement cost by analogy with civilian aircraft (see Table 27).

2 Weighted by the following relative projected populations in order of the presentations above:

1988:	0.0656	0.3084	0.1027	0.1038	0.0088	0.4108
1989:	0.0653	0.3112	0.0990	0.1028	0.0085	0.4132
1990:	0.0649	0.3143	0.0960	0.1015	0.0082	0.4150
1991:	0.0646	0.3191	0.0925	0.0998	0.0079	0.4160
1992:	0.0639	0.3237	0.0891	0.0977	0.0077	0.4179

SECTION 7: MODELS TO ESTIMATE WEIGHT PENALTIES DUE TO REGULATORY CHANGES

A. Introduction

The purpose of the models described in this section is to provide estimates of increased air carrier, commuter and general aviation costs due to changes in FAA regulations which cause weight increases in aircraft. Separate models were developed for air carrier aircraft, general aviation and commuter aircraft. All of the models capture the effects on U.S. aircraft only. Each model is discussed in turn below. This section also serves as the users' manual for the Lotus 1-2-3 models which accompany this document.

B. U.S. Air Carrier Model

Changes in FAA regulations often result in air carriers having to install additional equipment on-board their aircraft. There are two possible effects of the increased weight on airline operations:

- o Increased fuel consumption per hour of operation.
- o Foregone revenues if the weight increase is so large that it causes the airline to reduce the number of passengers it can carry.

The present model considers only the former effect.

Conceptually, the amount of fuel consumed per block hour should directly depend upon both the capacity of the aircraft (measured by available tons) and the actual loads carried (measured by loaded tons). Fuel consumption can also be affected by average stage length and the speed of the aircraft. Changes in FAA regulations would directly affect only one of the variables--loaded tons. If a model can be constructed which explains fuel consumption per block hour and this model includes loaded tons as one of the independent variables, then it would be possible to directly evaluate the effects of alternative FAA regulations on operating costs of air carriers. Such a model is described below.

1. Data

Data for this model were taken from the U.S. Department of Transportation's September 1985 issue of Aircraft Operating Cost and Performance Report.[140] This publication incorporates information on air carriers which filed schedules on CAB Form 41, "Report of Financial and Operating Statistics for Certified Air Carriers." This issue is the nineteenth and final report of a series of annual publications by the Department of Transportation.

The DOT report lists data in the following classifications: operation and carrier group, cabin configuration, equipment group, equipment type, carrier name and time period covered. For the present study, data on the operations of individual air carriers by aircraft type were incorporated into the model. This was the most disaggregate form of data available.

2. Estimation of Models

The general form of the model is as follows:

Gallons of Fuel Per Hour = f(tons available, tons used, speed, stage length)

Several alternative specifications of the models were attempted. It quickly became apparent that the data were collinear. This is not surprising since most of the independent variables tend to move with one another. For example, as stage length increases, tons available and tons used also increase.

In order to circumvent the collinearity problem, factor analysis was employed. The results of the factor analysis for the four types of aircraft are shown in Table 33. Using principal component analysis, the effects of the independent variables included in the model can be identified. The expanded equations are shown in Section 10, Appendix Table 10.

The predictive accuracy of the models is shown in Figures 1 through 4. Here, actual gallons versus estimated gallons from the model are plotted on the same graphs. In general, the models provide acceptable levels of accuracy. In perusing the charts, the reader will notice that there are some apparent outliers in the data. However, outlier tests indicated that the observations shown on the charts should, in fact, remain in the data base.

3. Estimating Impacts

The impacts of a regulatory change on air carrier operating costs are estimated by evaluating the differences in gallons of fuel consumed per hour for any aircraft type due to the change in weight mandated by the FAA. The effects on air carriers can then be evaluated by aggregating the block hour effects over the total fleet size of the aircraft in question and then adding the effects over time. The model developed here uses FAA Aviation Forecasts[141] to estimate the multiple year effects.

Estimating the effects can be separated conveniently into two steps. First the annual penalty for a given group of aircraft is estimated. Then the annual penalties for the period of time covered by FAA Aviation Forecasts are summed and discounted to develop estimates of net present value. The OMB-prescribed ten percent discount rate is used in the procedure, although the model can accommodate any discount rate. The equations for developing the annual penalty and the total penalty are shown below.

The annual penalty costs (AP) are based on the following formula:

$$AP_t = a * \frac{1}{(1+b_1)^t} * D * E * F$$

where

a = the change in the gallons consumed per block hour due to the weight increase estimated in the equation;

b = the annual change in fuel efficiency for the particular class of air carrier based on the period 1981-1985;

t = an exponential factor from 1-12, based on the year

D = estimated million airborne hours for the carrier group for the year, based on FAA Aviation Forecasts;

E = the estimated price of fuel for the year based on FAA Aviation Forecasts;

F = the ratio of block to airborne hours for the particular class of air carrier based on DOT Form 41 data.

The total penalty is defined as:

$$TP_j = \sum_t \frac{AP_{jt}}{(1 + i)^t},$$

where i = 10 percent, and j = aircraft type.

Table 33

FACTOR ANALYSIS RESULTS FOR AIR CARRIER AIRCRAFT*

Narrow Body, 2 Engines

Gal Per Block Hour =

$$839.1 + \underset{(9.09)}{75.6\ F_1} + \underset{(2.87)}{22.4\ F_2} - \underset{(-1.91)}{8.4\ (F_2)^2}$$

$$\text{Adj} - \overline{R}^2 = .66$$

Narrow Body, 3-4 Engines

Gal Per Block Hour =

$$1335.6 + \underset{(6.56)}{232.8\ F^1} + \underset{(6.65)}{153.7\ F_2} - \underset{(-1.96)}{26.9(F_1)^2} - \underset{(-1.86)}{14.03(F_2)^2}$$

$$\text{Adj} - \overline{R}^2 = .79$$

Wide Body, 2-3 Engines

Gal Per Block Hour =

$$2230.9 + \underset{(36.87)}{230.0\ F_1} + \underset{(37.49)}{278.9\ F_2} - \underset{(28.39)}{115.4(F_2)^2}$$

$$\text{Adj} - \overline{R}^2 = .78$$

Wide Body, 4 Engines

Gal Per Block Hour =

$$3492.4 - \underset{(35.42)}{184.6\ F_1} - \underset{(40.13)}{111.5(F_1)^2}$$

$$\text{Adj} - \overline{R}^2 = .49$$

*t - statistics in parentheses

Figure 1

2 ENGINE NARROW BODY

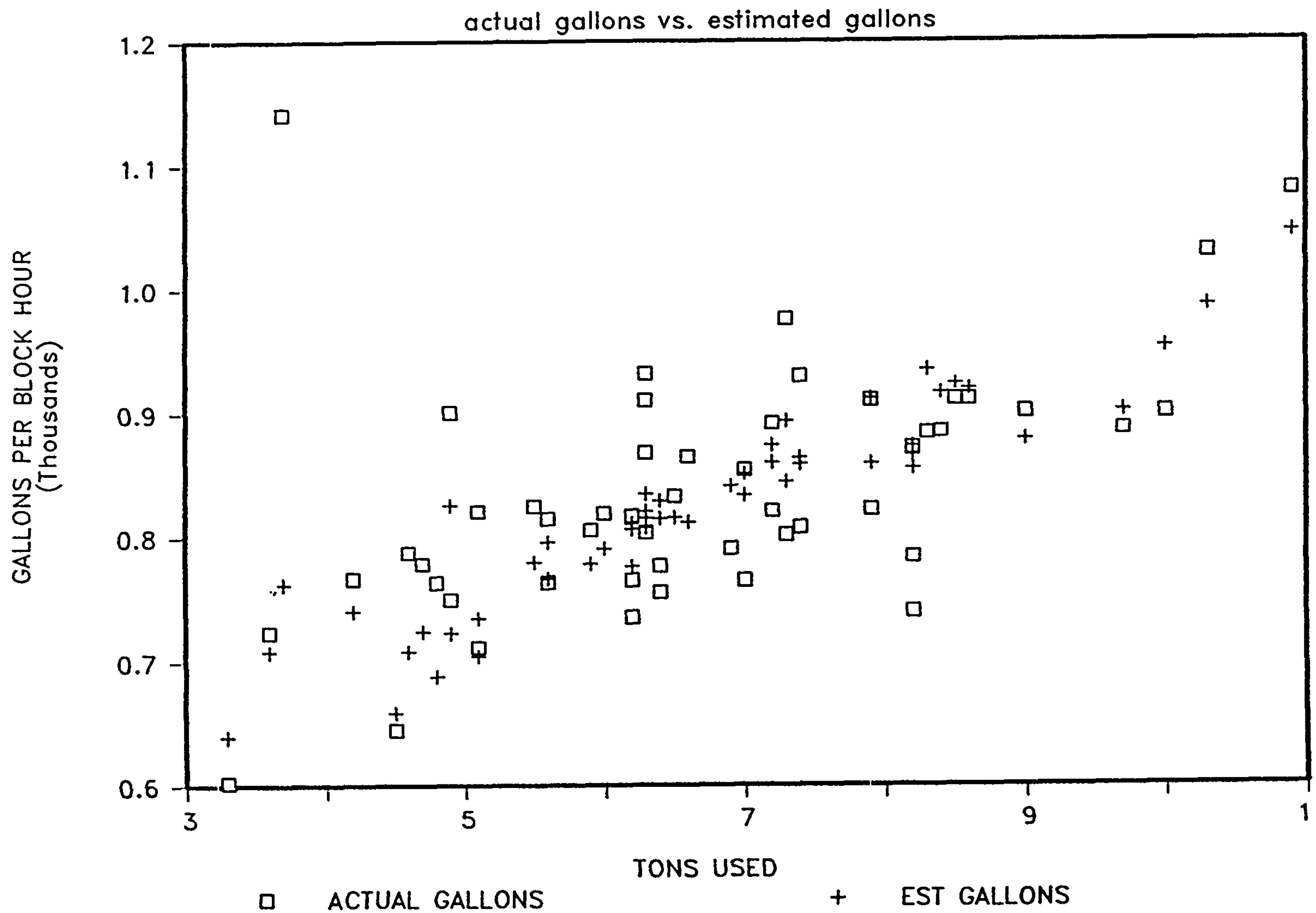


Figure 2

3 & 4 ENGINE NARROW BODY

actual gallons vs. estimated gallons

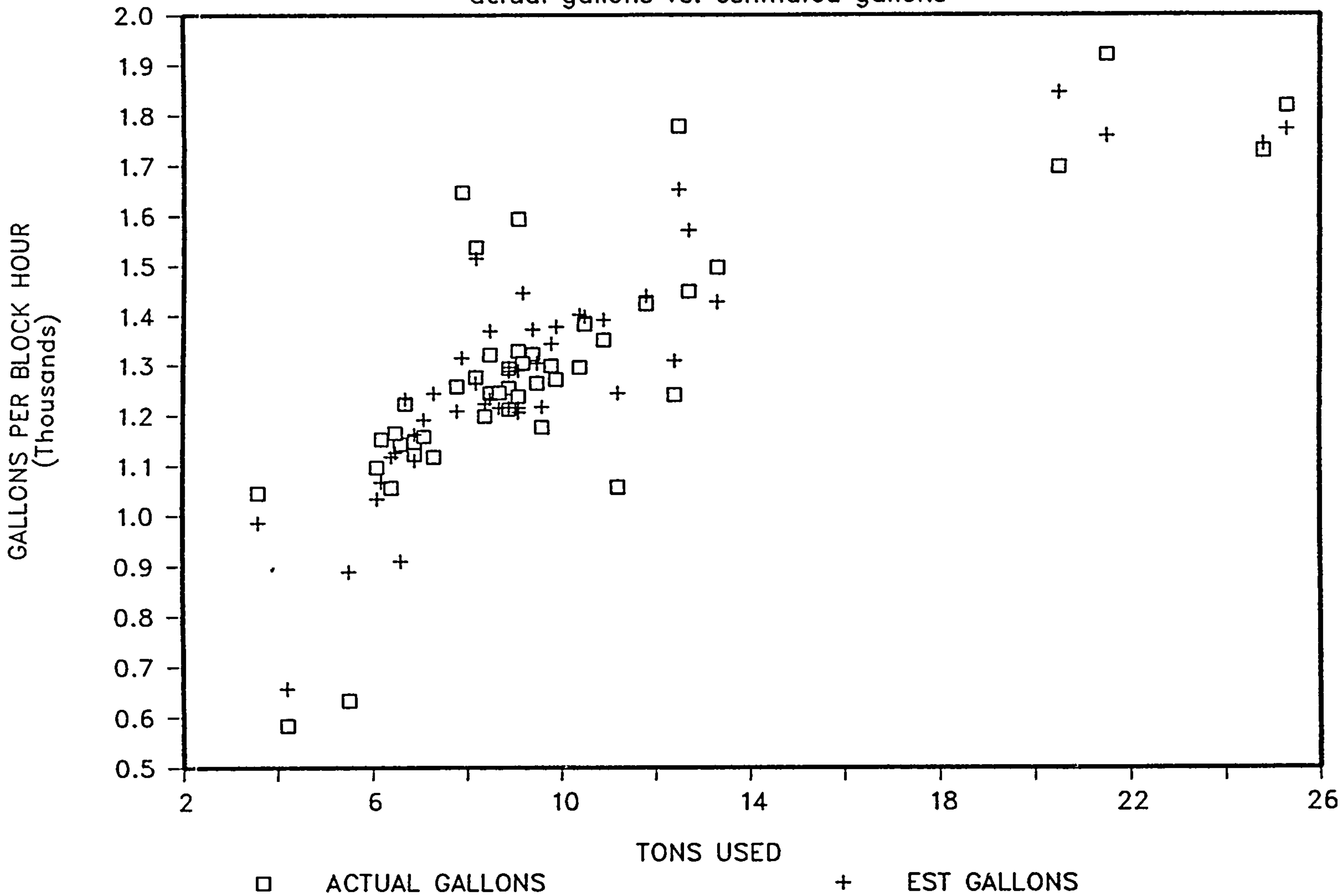


Figure 3

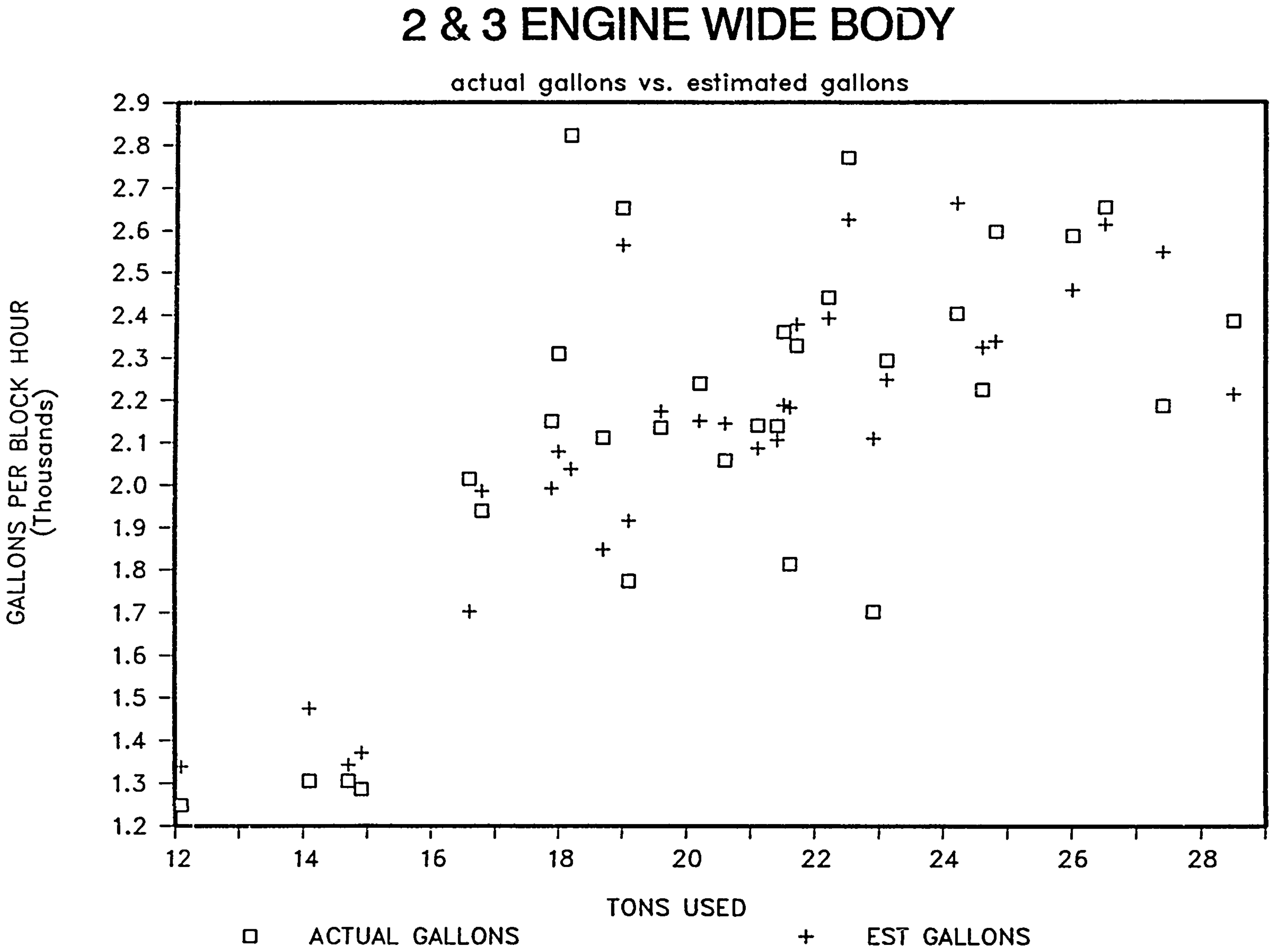
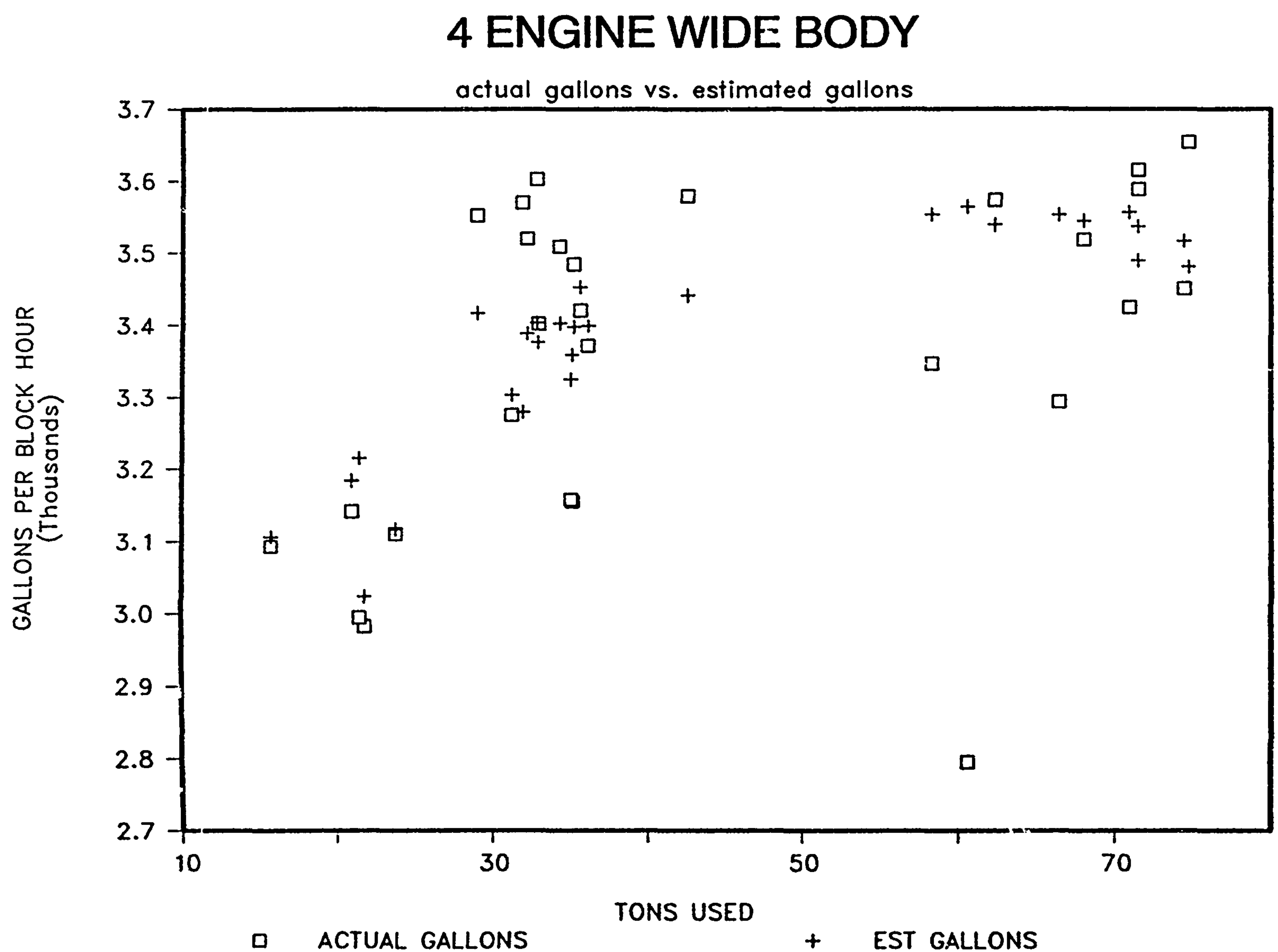

2 & 3 ENGINE WIDE BODY
actual gallons vs. estimated gallons
GALLONS PER BLOCK HOUR
(Thousands)
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
12
14
16
18
20
22
24
26
28
TONS USED
ACTUAL GALLONS
EST GALLONS

Figure 4



4 ENGINE WIDE BODY
actual gallons vs. estimated gallons
GALLONS PER BLOCK HOUR
(Thousands)
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
2.9
2.8
2.7
10
30
50
70
TONS USED
ACTUAL GALLONS
EST GALLONS

4. <u>Documentation for Air Carrier Lotus 1-2-3 Weight Penalty Model</u>

To run the model, load the file into the computer and begin the model by pressing ALT-R. You will immediately view the screen shown below:

```
                                                      READY
BA2:
ENTER DESCRIPTION OF REGULATORY CHANGE:
          BA        BB        BC        BE        BF        BG        BH

2
3
4
5
6              Narrow Body 2 Engines - 1
7
8              Narrow Body 3 & 4 Engines - 2
9
10             Wide Body 2 & 3 Engines - 3
11
12             Wide Body 4 Engines - 4
13
14
15
16                  Gellman Research Associates, Inc.
17
```

First, you will be asked to enter a description of the regulatory change which is being proposed. For example, if the user wants to test the cost of adding new doors to an airplane, he would type, "NEW DOORS" and press return.

The computer then asks you the year the regulation is going to occur. Simply type in the year and press return.

The computer will next ask you if you would like to view the weight costing model in the same year's discounted dollars which you had previously entered. Type "Y" and press return if you wish to view the weight costing model in discounted dollars beginning the same year. Or type "N" if you do not with to view the model in that year's dollars. If you type "N" for no, the computer will ask you which year you wish to begin discounting the cost of the increased weight.

Next, you will be instructed to enter the weight increase in pounds. Simply type in the pounds and press return.

Then enter the discount rate. If, for example, the discount rate is 12 percent, then type .12 and press return.

Finally, the computer will ask you which airplane class you wish to view. You have a choice of viewing four airplane classes which are present on the screen. Simply type the corresponding number adjacent to the airplane class

in which you are interested and press return. The computer will then prompt you with the screen listing your choices of individual air carriers which you are able to view in that airplane model for which you wish to view results. The model also offers you the choice of viewing the entire group as a whole.

The computer will then show you in chart form the year, the corresponding penalty in dollar figures for that year, and the discounted dollar figures which you specified previously. You are also given the option to view another airplane; simply type "Y" for yes to continue the model.

READY

AG7: 1987

AQ AR AS AT AU AV

1 WEIGHT PENALTY DUE TO REGULATORY CHANGE:
2 450 POUNDS
3

4	Narrow Body	2 Engines	1987
5	Year	Penalty	Dollars
6		(current year $)	
7			
8	1987	$16,884,830.59	$16,884,830.59
9	1988	$21,104,772,76	$19,186,157.06
10	1989	$24,913,489.10	$20,589,660.41
11	1990	$28,066,730.08	$21,086,949.72
12	1991	$31,097,599.90	$21,240,079.16
13	1992	$34,456,033.39	$21,394,485.84
14	1993	$37,713,580.54	$21,288,333.02
15	1994	$41,283,460.24	$21,184,942.77
16	1995	$45,590,778.27	$21,268,434.53
17	1996	$50,143,108.72	$21,265,572.99
18	1997	$55,424,677.12	$21,368,612.33
19	1998	$61,188,075.06	$21,446,047.03
20	TOTAL	$447,867,075.06	$248,204,105.47

C. U.S. Commuter Model

The model described in this section estimates increased commuter aircraft costs due to changes in FAA regulations which cause weight increases in aircraft. Changes in FAA regulations often result in commuters having to install additional equipment on-board their aircraft. There are two possible effects of the increased weight on airline operations:

- o Increased fuel consumption per hour of operation;
- o Foregone revenues if the weight increase is so large that it causes the airline to reduce the number of passengers it can carry.

The present model considers only the former effect.

Conceptually, the amount of fuel consumed per block hour by commuter aircraft should directly depend on both the capacity of the aircraft (measured by maximum landing weight or payload) and the speed of the aircraft (measured by block speed). Fuel consumption can also be affected by seating, number of engines and whether or not the aircraft is pressurized. Changes in FAA regulations would directly affect only one of the variables--capacity. If a model can be constructed which explains fuel consumption per block hour and this model includes maximum landing weight as one of the independent variables, then it would be possible to directly evaluate the affects of alternative FAA regulations on operating costs of commuter aircraft. Such a model is described below.

1. Data

Data for this model were taken from the Business and Commercial Aviation's Aircraft Operating and Performance Data (1982-1987).[142] The handbook publishes data in the following classifications: manufacturer model, characteristics, dimensions, power, weight, takeoff, climb, limits, cruise and productivity factors.

The number of units for each model was obtained from the 1986 FAA Census of U.S. Civil Aircraft and the 1987 FAA Annual Report. Data on the operations of individual air carriers by aircraft type were incorporated into the model. This was the most disaggregate form of data available.

2. Estimation of Models

The general form of the model is as follows:

Gallons of fuel per block hour = f(maximum landing weight, block speed)

The predictive accuracy of the model is shown in Figure 5. Here, actual gallons versus estimated gallons from the model are plotted on the same graph. In general, the model provides acceptable levels of accuracy. In perusing the charts, the reader will notice that there are some apparent outliers in the data. Outlier tests indicate that the observations for turbojet aircraft shown on the chart should, in fact, be deleted from the model.

3. Estimating Impacts

The impacts of a regulatory change on commuter aircraft operating costs are estimated by evaluating the differences in gallons of fuel consumed per hour for each aircraft type due to the change in weight mandated by the FAA. The effects on commuter aircraft in general can then be evaluated by aggregating the effects over the total fleet size of the aircraft in question and then adding the effects over time. The model developed here uses FAA Aviation Forecasts to estimate the future number of hours of flight for commuters.

Estimating the effects can be separated conveniently into two steps. First, the annual penalty for a given group of aircraft is estimated. Then the annual penalties for the period of time covered by FAA Aviation Forecasts are summed and discounted to develop estimates of net present value. The OMB-prescribed 10 percent discount rate is used in the procedure, although the model can accommodate any discount rate. The equations for developing the annual penalty and the total penalty are shown below.

The annual penalty costs (AP) are based on the following formula:

$$AP_t = a * \frac{1}{(1+b_1)^t} * D * E$$

Where

a = the change in the gallons consumed due to the weight increase estimated in the equation;

b = the annual change in fuel efficiency for the particular class of aircraft based on the period 1982-1987;

t = an exponential factor from 1-12 based on the year;

D = the estimated airborne hours for the aircraft group for the year, based on FAA Aviation Forecasts;

E = the estimated price of fuel for the year based on FAA Aviation Forecasts;

The total penalty is defined as:

$$TP_j = \sum_t \frac{AP_j}{(1+i)^t}$$

where

i = 10%

j = aircraft type

The model estimated for commuters is shown below:

Fuel burned per block hour = $e^{-10.2218} S^{1.386132175} W^{.791031811}$

F = fuel burn

W = maximum landing weight

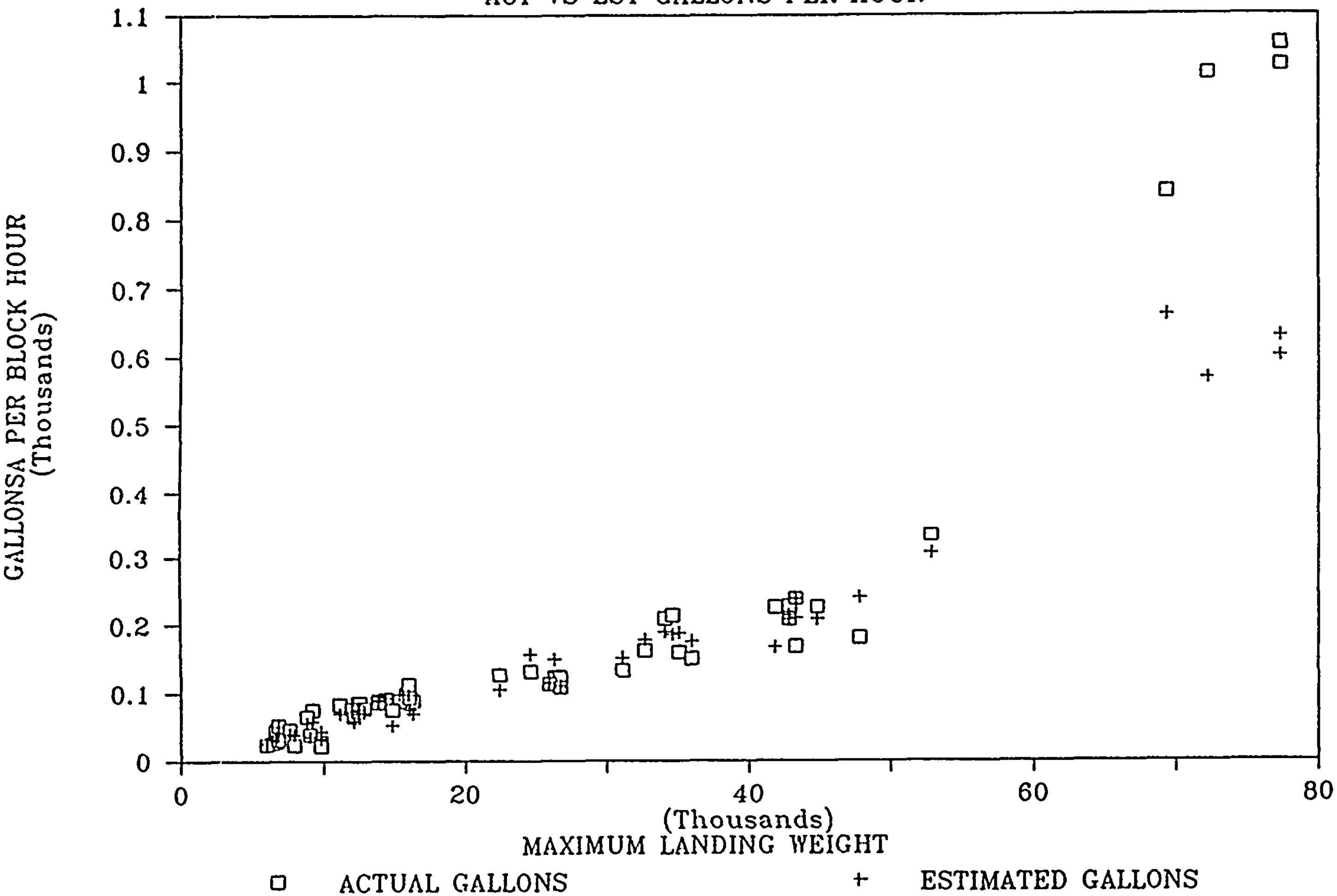
S = speed

Outlier: All turbojets $R^2 = .94$

Figure 5

COMMUTER AIRCRAFT

ACT VS EST GALLONS PER HOUR



4. Documentation for Commuter Lotus 1-2-3 Weight Penalty Model

Retrieve the file COMMAC to begin the macro. When the file is called up, the user is automatically entered into a menu-driven system where he is presented with four choices:

1) to enter the model directly,

2) to update assumptions within the model,

3) to exit the model and to save any changes which were made by inputting new assumptions.

To input new assumptions, simply choose the corresponding command. Your new assumptions will automatically be saved when you exit the model.

To begin the model, use the arrow key to select GRA model and press return. You will immediately view the screen below:

```
DJ6:                                                        READY
ENTER DESCRIPTION OF REGULATORY CHANGE:

          DJ     DK     DL     DM     DN     DO     DP     DQ
6
7
8                     GELLMAN RESEARCH ASSOCIATES
9
10               WEIGHT COSTING MODEL FOR COMMUTER AIRCRAFT
11
12
13                  1  LESS THAN 19 SEATS
14
15                  2  MORE THAN 19 SEATS
16
17
18
19
```

You will first be asked to type in a description of the regulatory change which you are proposing. For example, if the user wants to test the cost of adding new landing gear to an aircraft, he would type "NEW LANDING GEAR" and press return.

The user is then asked what year this regulation is going to occur. The model works for years 1988 through 1999. Simply type in the year and press return.

You are then asked if you would like to view the weight model in this year's dollars; you are to answer with a yes (y) or no (n). If you answer no, the model will then ask you in what year's dollars you wish to view the

cost assumptions. Simply type in the year. For example, suppose you are interested in estimating the effect in 1988 dollars of a regulation that will go into effect in 1990. You would type 1988 for year's dollars. Again, the model works for years 1988 through 1999.

You are then asked to enter the weight increase in pounds; simply type this number and press enter.

Next, enter the discount rate as a decimal fraction, e.g., .10.

After inputting these data variables, you are asked which commuter class to view; simply type in the number corresponding to the class of aircraft you wish to view. You will then view a screen with a list of aircraft comprising the chosen aircraft category. If you wish to view the remaining aircraft in the class, just type yes (y), at the prompt, and hit return. You are then asked if you wish to view the previous screen. You have an option of viewing each screen twice before choosing which aircraft to view.

The last two choices in each category of commuters are a special option. The first offers the user the choice to run the model on all the commuter aircraft in the category and to view their cumulative sum. The second of these choices offers the viewer to see a running total of all the previous planes he has looked at. From the first aircraft viewed, the model keeps a tabulation of costs, adding each current planes costs with the costs of the planes previously viewed. The count is automatically reset to zero after a viewer chooses to see the effects of all the planes in one category or if the viewer decides to run the model again with new assumptions.

The final screen of the model has the weight penalty in the current year's dollars and to the right of that column, the penalty in the year's dollars which the user specified. The screen also shows the regulatory change proposed, the weight increase in pounds, the discount rate, and the model of the plane.

The user is then prompted to print the screen. By typing "y" the user will get a printout of the screen through his printer, assuming he has the defaults of this file correctly set to his printer.

The final prompt asks the user if he wishes to view another plane. If the user types "y" he will be shown the first screen again with the two commuter categories he has an option to view. The cycle begins again.

If the user wishes to change any assumptions, or simply to quit the model, typing "n" at the prompt to view another airplane will bring the viewer back to the original screen, where he may begin the model again with new assumptions or he may choose any of the other options, including exiting the model and saving any new aircraft assumptions which he may have entered previously into the file.

D. U.S. General Aviation Model

The general aviation model provides estimates of increased GA aircraft cost due to changes in FAA regulations which cause weight increases in aircraft. Changes in FAA regulations often result in GA operators having to install additional equipment on-board their aircraft. Such a regulation may cause increased fuel consumption per hour of operation for the aircraft. The present model considers this effect.

Evaluations were made assuming GA aircraft cruise at an average 55 percent power setting and the average trip is 300 nautical miles. Conceptually, the amount of fuel consumed should directly depend on both the capacity of the aircraft (measured by maximum takeoff weight or payload) and the speed of the aircraft (measured by speed at a 55 percent power setting). Fuel consumption can also be affected by number of engines, vintage of the aircraft, trip length and whether the aircraft is pressurized. Changes in FAA regulations causing weight increases would directly affect only one of the variables: capacity. If a model can be constructed which explains fuel consumption for a 300 nautical mile trip at 55 percent maximum power, and this model includes capacity as one of the independent variables, it would be possible to directly evaluate the effects of alternative FAA regulations on operating costs of general aviation aircraft. Such a model is described below.

1. Data

Data for this model were taken from the 1982-1987 issues of Business and Commercial Aviation's Planning and Purchasing Handbook.[143] These are annual publications which outline pertinent data on current GA aircraft. The number of units for each aircraft model was obtained from the 1986 FAA Census of U.S. Civil Aircraft. The Planning and Purchasing Handbook lists data in the following classifications: manufacturer or model, characteristics, dimensions, power, weights, limits, takeoff, climb, cruise, VFR ranges, and IFR missions. Data on the operation of individual GA aircraft by aircraft type were incorporated into the model. This was the most disaggregate form of data available.

2. Estimation of Models

The general form of the model is as follows:

Gallons of fuel per hour = f(maximum takeoff weight, speed at 55%)

except for turbojets for which the form is:

Gallons of fuel per hour = f(maximum takeoff weight)

The predictive accuracy of the model is shown in Figures 6 through 9. Here, actual gallons versus estimated gallons from the model are plotted on the same graphs. In general, the models provide acceptable levels of accuracy. In perusing the charts, the reader will notice that there are some apparent outliers in the data. However, outlier tests indicate that the observations shown on the chart should, in fact, remain in the data base.

Figure 6

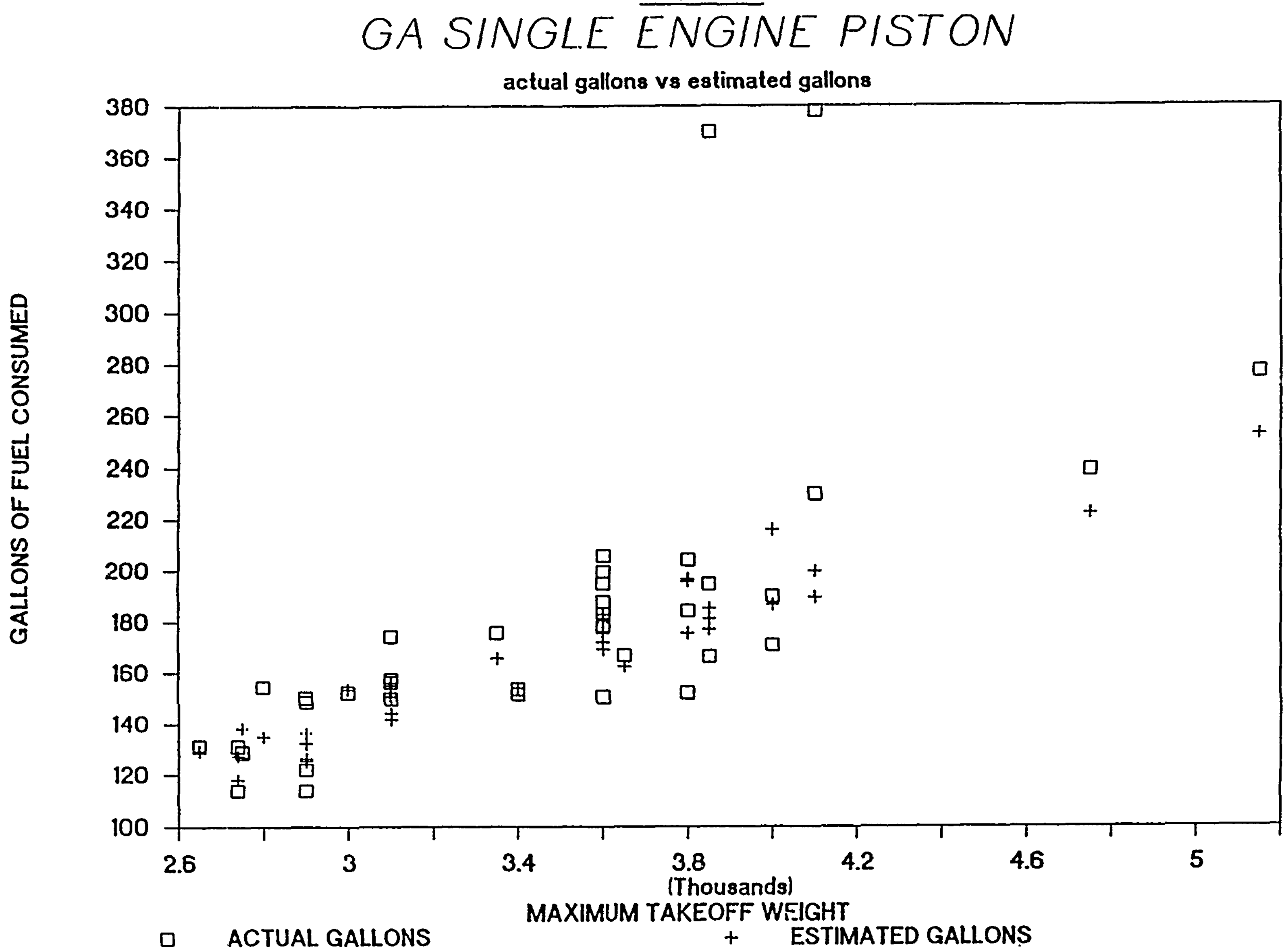

GA SINGLE ENGINE PISTON
actual gallons vs estimated gallons
GALLONS OF FUEL CONSUMED
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
2.6
3
3.4
3.8
4.2
4.6
5
(Thousands)
MAXIMUM TAKEOFF WEIGHT
ACTUAL GALLONS
ESTIMATED GALLONS

Figure 7

GA MULTI ENGINE PISTON

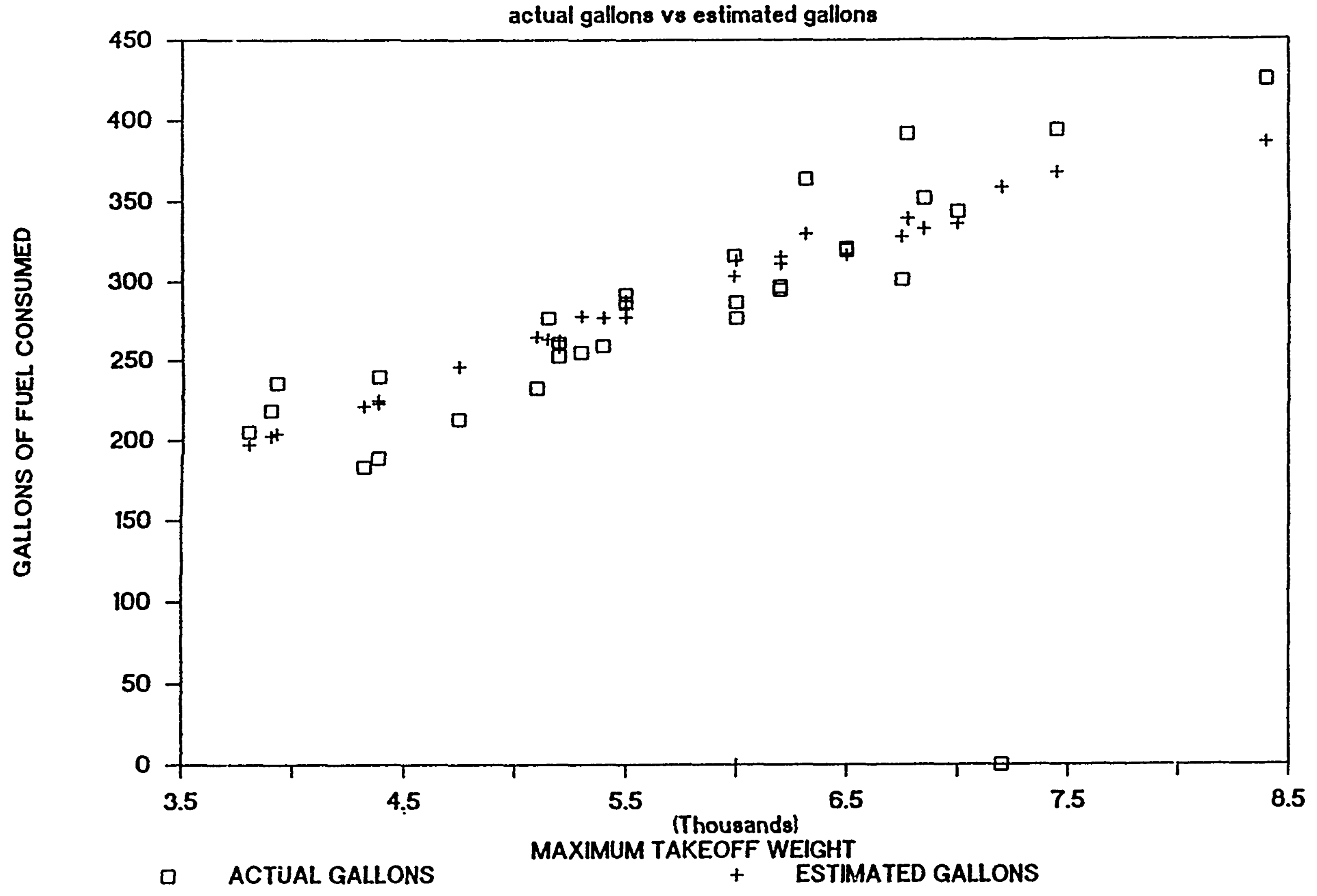


Figure 8

GA TURBOPROP

actual gallons vs estimated gallons

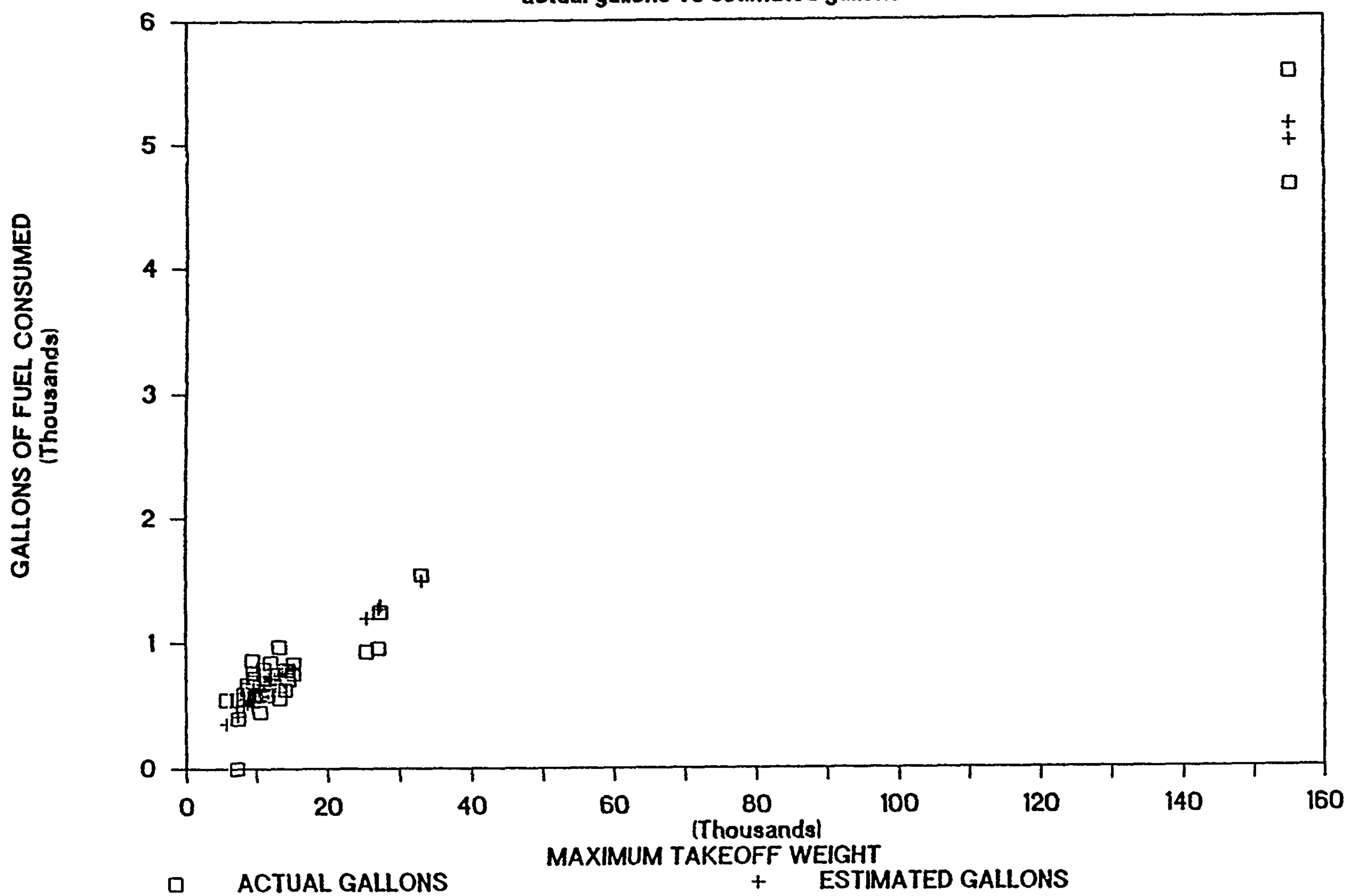
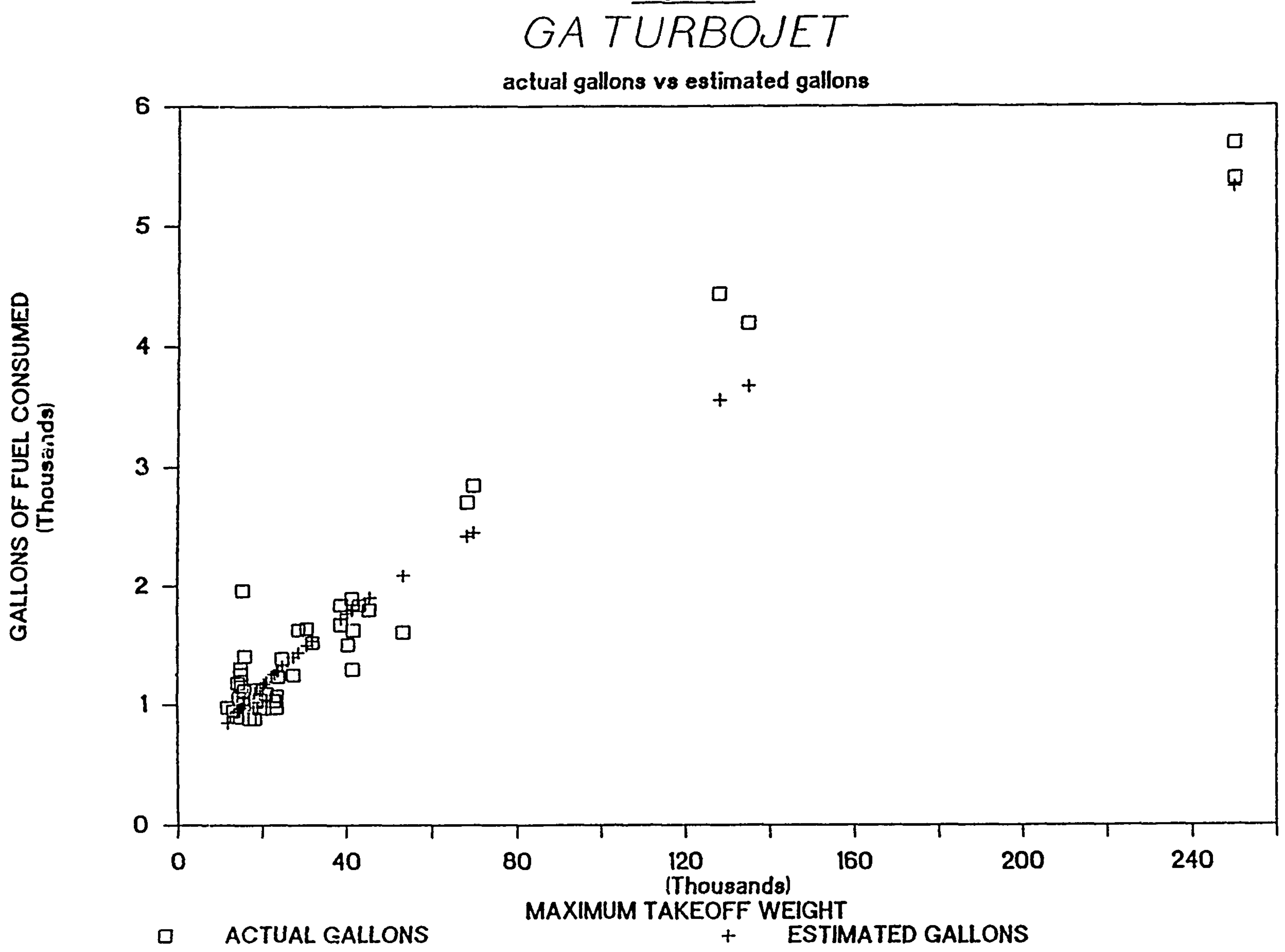


Figure 9


GA TURBOJET
actual gallons vs estimated gallons
GALLONS OF FUEL CONSUMED
(Thousands)
0
1
2
3
4
5
6
0
40
80
120
160
200
240
(Thousands)
MAXIMUM TAKEOFF WEIGHT
ACTUAL GALLONS
ESTIMATED GALLONS

3. Estimating Impacts

The impacts of a regulatory change on GA aircraft operating costs are estimated by evaluating the differences in gallons of fuel consumed per 300 nautical mile increments at 55 percent speed for any aircraft type due to the change in weight mandated by the FAA. The effects on GA aircraft can then be evaluated by aggregating the effects over the total fleet size of the aircraft in question and then adding the effects over time. The model developed here uses FAA Aviation Forecasts to estimate the future number of hours of flight by GA aircraft.

Estimating the effects can be separated conveniently into two steps. First, the annual penalty for a given group of aircraft is estimated. Then the annual penalties for the period of time covered by FAA Aviation Forecasts are summed and discounted to develop estimates of net present value. The OMB-prescribed 10 percent discount rate is used in the procedure, although the model can accommodate any discount rate. The equations for developing the annual penalty and the total penalty are shown below.

The annual penalty costs (AP) are based on the following formula:

$$AP_t = a * \frac{1}{(1+b_1)^t} * D * E$$

Where

a = the change in the gallons consumed due to the weight increase estimated in the equation;

b = the annual change in fuel efficiency for the particular class of aircraft based on the period 1982-1987;

t = an exponential factor from 1-12 based on the year;

D = the estimated airborne hours for the aircraft group for the year, based on FAA Aviation Forecasts;

E = the estimated price of fuel based on FAA Aviation Forecasts;

The total penalty is defined as:

$$TP_j = \sum_t \frac{AP_j}{(1+i)^t}$$

where

i = 10%

j = aircraft type.

Table 34 summarizes the estimated models for GA-piston aircraft, multi-engine piston and turboprop aircraft and turbojet aircraft.

Table 34

GENERAL AVIATION FUEL BURN MODELS

F = fuel burn @ 300 N.M.

W = maximum takeoff weight

S = speed @ 55%

P = pressure dummy (0 = no, 1 = yes)

T = turboprop dummy (0 = no, 1 = yes)

Single Engine Piston

Fuel burned per trip = $(0.102)(1.127)^{P}W^{1.257}S^{-0.580}$

adj. $R^2 = 0.830$

Outliers:

Cessna Cent. CE-210R

Cessna Turbo Cent. CE-T210R

Cessna Cara Jan 1 CE-208

Multi-Engine Piston and Turboprop

Fuel burned per trip = $(0.0704)(1.161)^{T}W^{0.773}S^{0.317}$

adj. $R^2 = 0.896$

Turbojet/Turbofan

Fuel burned per trip = $2.927W^{0.604}$

adj. $R^2 = 0.888$

Outlier: Aerospatiale SN-601

4. Documentation for General Aviation Lotus 1-2-3 Weight Penalty Model

The model is composed of three files. The main file, GAEX, runs the menu. The remaining files, GA and GAHOURS, deal with aircraft assumptions and aircraft hours, respectively. Retrieve the file GAEX to begin the macro.

When the file is called up, the user is automatically entered into a menu-driven system where he is presented with four choices. The choices are:

1) to enter the model directly,

2) to update assumptions within the model,

3) to import the updates, and

4) to exit the model and to save any changes which were made by importing new assumptions.

It is important for the user to realize that if he decides to update certain assumptions within the model, such as an individual aircraft's weight characteristics, he must then import these updates into the GAEX file. This is because assumptions are updated in the file named GA, and converted to hours which is transposed in the file GAHOURS. To input new assumptions, simply choose the corresponding command. Your new assumptions will automatically be saved when you exit the model. Please note that this is important since the model will not import the updated assumptions automatically unless specifically told to do so.

To begin the model, use the arrow key to select GRA model and press return. You will immediately view the screen below:

```
DM6:                                                        READY
ENTER DESCRIPTION OF REGULATORY CHANGE:

          DM      DN      DO      DP      DQ      DR      DS      DT
 6
 7
 8                    GELLMAN RESEARCH ASSOCIATES
 9
10                WEIGHT COSTING MODEL FOR GA AIRCRAFT
11
12
13                1  SINGLE ENGINE PISTON
14
15                2  MULTI ENGINE PISTON
16
17                3  TURBOPROP
18
19                4  TURBOJET/TURBOFAN
20
```

You will first be asked to type in a description of the regulatory change which you are proposing. For example, if the user wants to test the cost of adding new landing gear to an aircraft, he would type "NEW LANDING GEAR" and press return.

The user is then asked what year this regulation is going to occur. The model works for years 1988 through 1999. Simply type in the year and press return. You are then asked if you would like to view the weight model in this year's dollars; you are to answer with a yes "y" or no "n". If you answer no, the model will then ask you in what year's dollars you wish to view the cost assumptions. Simply type in the year. For example, suppose you are interested in a regulation that will take effect in 1990 but want to know the effect in 1988 dollars. Type 1988 here. Again, the model works for years 1988 through 1999.

You are then asked to enter the weight increase in pounds; simply type this number and press enter. Next, enter the discount rate as a decimal fraction, e.g., .10.

After finishing inputting these data variables, you are finally asked which GA class to view; simply type in the number corresponding to the class of aircraft you wish to view. You will then view a screen with a list of aircraft comprising the chosen aircraft category. If you wish to view the remaining aircraft in the class, just type yes "y", at the prompt, and hit return. You are then asked if you wish to view the previous screen. You have an option of viewing each screen twice before choosing which aircraft to view.

The last two choices in each category of GA aircraft are a special option. The first offers the user the choice to run the model on all the aircraft in the category and to view their cumulative sum. The second of these choices offers the viewer to see a running total of all the previous planes he has looked at. From the first aircraft viewed, the model keeps a tabulation of costs, adding each current planes' costs with the costs of the planes previously viewed. The count is automatically reset to zero after a viewer chooses to see the effects of all the planes in one category or if the viewer decides to run the model again with new assumptions.

The final screen of the model (below) has the weight penalty in the current year's dollars and to the right of that column, the penalty in the year's dollars which the user specified. The screen also shows the regulatory change proposed, the weight increase in pounds, the discount rate, and the model of the plane.

The user is then prompted to print the screen. By typing "y" the user will get a printout of the screen through his printer. The final prompt asks the user if he wishes to view another plane. If the user types "y" he will be shown the first screen again with the four GA categories he has an option to view. The cycle begins again.

If the user wishes to change any assumptions, or simply to quit the model, typing "n" at the prompt to view another airplane bring the viewer back to

the original screen, where he may begin the model again with new assumptions or he may choose any of the other options, including exiting the model and saving any new aircraft assumptions which he may have imported previously into the file.

E12: READY

WOULD YOU LIKE TO PRINT THIS SCREEN? (Y/N)

	CN	CO	CP	CQ	CR
2	WEIGHT PENALTY DUE TO REGULATORY CHANGE:				
3	NEW LANDING GEAR			200 lb. Weight Increase	
4				0.1 Discount Rate	
5	BEECH A36				1991
6	Year		Penalty		Dollars
7					
8	1988		$0.00		$0.00
9	1989		$0.00		$0.00
10	1990		$15,554,648.51		$17,110,113.36
11	1991		$15,779,531.73		$15,779,531.73
12	1992		$16,009,310.80		$14,553,918.91
13	1993		$16,317,856.52		$13,485,831.84
14	1994		$16,669,866.30		$12,524,317.28
15	1995		$17,073,334.08		$11,661,316.91
16	1996		$17,467,441.20		$10,845,906.70
17	1997		$18,036,861.54		$10,181,338.12
18	1998		$18,567,063.76		$9,527,839.50
19	1999		$19,223,311.60		$8,967,816.73
20					
21	Total		$170,699,226.04		$124,637,931.08

SECTION 8: PROBABILITIES OF THIRD-PARTY DAMAGE

A. Introduction

This chapter reviews a special run of the National Transportation Safety Board (NTSB) aviation database for the years 1983 through 1986. The purpose of this run was to develop probabilities of third-party property damages attributable to aviation accidents. Third-party damage is defined as damage to property other than aircraft involved in the accident. The NTSB data cover air carrier, general aviation and air taxi accidents. No data on military accidents were available.

B. Property Damage Distribution

The "Factual Report" included as part of the NTSB data set provides information on eleven alternative types of third-party property damage:

1. None
2. Residence
3. Residential area
4. Commercial building
5. Vehicles
6. Airport facilities
7. Trees
8. Crops
9. Fence
10. Wire/poles
11. Other property

A total of 6800 accidents had information on third-party property damage. These accidents were distributed by phase of flight in the following way:

- o On-ground accidents--345 (5.1 percent)
- o Takeoff accidents--1651 (24.3 percent)
- o Approach accidents--3494 (51.4 percent)
- o In-air accidents--121 (1.8 percent)
- o Unknown phase--1189 (17.5 percent)

In each phase of flight, there is information available on the number of accidents occurring in each damage category for air carriers, air taxis and general aviation.

The following tables provide information on the distribution of third-party property damage segregated by user group and phase of flight. Table 35 presents information for takeoff and on-ground accidents, as well as accidents occurring during unknown phases of flight. Distributions for approach, in-air and total accidents are shown in Table 36.

Each entry for each user group shows the percentage of the user group's accidents occurring during a particular phase of flight that resulted in one of the eleven third-party property categories. For example, 58 percent of the

air carrier accidents occurring on takeoff resulted in no third-party property damage. Two percent of the air carrier accidents taking place on takeoff resulted in damages to commercial buildings, while 21 percent resulted in damage to airport facilities.

For most cost-benefit applications, the most relevant entries are those shown for total accidents in Table 36. These can be used to forecast the third-party damage effects of accidents at issue in either regulatory proceedings or in developing estimates of benefits for establishment of new airport or airway facilities. For example, the total figures in Table 36 suggest that over 57 percent of all air carrier accidents would result in no third-party property damage. Approximately 72 percent of air taxi accidents and 73 percent of general aviation accidents would also result in no third-party property damage. When air carrier accidents do cause third-party damage, it is airport facilities that are most likely to be affected. This is due to the air carrier approach and takeoff accidents which cause airport facility damage.

In contrast, trees are the most likely category of third-party property to be affected by air taxi and general aviation accidents. Again, this is due to the large share of takeoff and approach accidents which result in damage to trees.

The figures in Tables 35 and 36 may be particularly relevant for evaluating the appropriateness of establishing new FAA airport and airway facilities. To the extent that these facilities will have an effect on different types of accidents, data in Tables 35 and 36 will allow a cost-benefit analyst to focus on those types of accidents most likely to be prevented by the facilities and equipment under consideration. For example, a new glide-slope at an airport would have the primary effect of reducing approach accidents. For all three user groups, the most likely outcome of such accidents would be no third-party property damage. The next most common air carrier and air taxi accident type would be damage to airport facilities, while the most common type of accident for general aviation accidents would be damage to trees. To the extent that either airport facilities or trees present particular hazards at airports under consideration for a glide-slope, the FAA might adjust estimated benefits.

Section 10, Appendix Table 11 presents the raw data used to derive the percentages shown in Tables 35 and 36.

TABLE 35

PERCENT CHANCE THAT AN ACCIDENT WILL RESULT IN NON-AIRCRAFT PROPERTY DAMAGE BY PROPERTY TYPE, PHASE OF FLIGHT, AND USER CLASS

PHASE: UNKNOWN	None	Resid	Resid Area	Comm'l Bldg	Vehicle	Airport Facil	Trees	Crops	Fence	Wires/ Poles	Other
AIR CARRIER	70.37%	3.70%	3.70%	0.00%	7.41%	7.41%	7.41%	3.70%	0.00%	7.41%	3.70%
AIR TAXI	67.31%	2.88%	0.00%	0.96%	0.00%	2.88%	18.27%	2.88%	1.92%	2.88%	2.88%
GENERAL AVIATION	75.61%	1.13%	0.38%	0.38%	1.61%	1.61%	11.34%	3.31%	1.61%	4.06%	2.08%
TOTAL	74.77%	1.35%	0.42%	0.42%	1.60%	1.85%	11.86%	3.28%	1.60%	4.04%	2.19%

PHASE: ON GROUND	None	Resid	Resid Area	Comm'l Bldg	Vehicle	Airport Facil	Trees	Crops	Fence	Wires/ Poles	Other
AIR CARRIER	44.44%	0.00%	0.00%	5.56%	33.33%	11.11%	0.00%	0.00%	0.00%	0.00%	5.56%
AIR TAXI	67.50%	2.50%	0.00%	2.50%	5.00%	2.50%	0.00%	0.00%	0.00%	5.00%	15.00%
GENERAL AVIATION	65.85%	0.00%	0.00%	2.09%	12.20%	4.88%	2.09%	0.00%	1.74%	2.44%	8.71%
TOTAL	64.93%	0.29%	0.00%	2.32%	12.46%	4.93%	1.74%	0.00%	1.45%	2.61%	9.28%

PHASE: TAKEOFF	None	Resid	Resid Area	Comm'l Bldg	Vehicle	Airport Facil	Trees	Crops	Fence	Wires/ Poles	Other
AIR CARRIER	58.33%	0.00%	0.00%	2.08%	4.17%	20.83%	10.42%	0.00%	0.00%	4.17%	8.33%
AIR TAXI	68.22%	1.87%	0.93%	0.93%	3.74%	6.54%	12.15%	0.93%	4.67%	5.61%	3.74%
GENERAL AVIATION	68.45%	0.74%	0.47%	0.94%	2.07%	2.94%	13.50%	4.08%	3.48%	3.28%	3.74%
TOTAL	68.14%	0.79%	0.48%	0.97%	2.24%	3.69%	13.33%	3.76%	3.45%	3.45%	3.88%

* Percentages may sum to more than 100% because of multiple citations per accident.

TABLE 36

PERCENT CHANCE THAT AN ACCIDENT WILL RESULT IN NON-AIRCRAFT PROPERTY DAMAGE BY PROPERTY TYPE, PHASE OF FLIGHT, AND USER CLASS

PHASE: APPROACH	None	Resid	Resid Area	Comm'l Bldg	Vehicle	Airport Facil	Trees	Crops	Fence	Wires/ Poles	Other
AIR CARRIER	55.42%	1.20%	0.00%	2.41%	3.61%	18.07%	13.25%	1.20%	6.02%	6.02%	2.41%
AIR TAXI	75.76%	0.43%	0.00%	0.00%	3.03%	7.36%	6.93%	1.30%	0.87%	5.63%	3.03%
GENERAL AVIATION	75.31%	0.53%	0.28%	0.69%	1.60%	3.84%	9.12%	1.89%	3.24%	2.80%	3.05%
TOTAL	74.87%	0.54%	0.26%	0.69%	1.75%	4.41%	9.07%	1.83%	3.15%	3.06%	3.03%

PHASE: IN AIR	None	Resid	Resid Area	Comm'l Bldg	Vehicle	Airport Facil	Trees	Crops	Fence	Wires/ Poles	Other
AIR CARRIER	66.67%	0.00%	0.00%	0.00%	0.00%	0.00%	33.33%	0.00%	0.00%	0.00%	0.00%
AIR TAXI	70.59%	0.00%	0.00%	0.00%	5.88%	5.88%	17.65%	0.00%	0.00%	0.00%	0.00%
GENERAL AVIATION	67.33%	0.00%	0.99%	0.99%	0.99%	0.00%	13.86%	4.95%	5.94%	3.96%	1.98%
TOTAL	67.77%	0.00%	0.83%	0.83%	1.65%	0.83%	14.88%	4.13%	4.96%	3.31%	1.65%

PHASE: TOTAL	None	Resid	Resid Area	Comm'l Bldg	Vehicle	Airport Facil	Trees	Crops	Fence	Wires/ Poles	Other
AIR CARRIER	57.54%	1.12%	0.56%	2.23%	7.26%	16.20%	10.61%	1.12%	2.79%	5.03%	4.47%
AIR TAXI	71.54%	1.40%	0.20%	0.60%	2.81%	5.81%	10.22%	1.40%	1.80%	4.81%	4.01%
GENERAL AVIATION	73.11%	0.65%	0.34%	0.77%	2.21%	3.22%	10.32%	2.63%	2.99%	3.14%	3.27%
TOTAL	72.59%	0.72%	0.34%	0.79%	2.38%	3.75%	10.32%	2.50%	2.90%	3.31%	3.35%

* Percentages may sum to more than 100% because of multiple citations per accident.

SECTION 9: ADJUSTMENT METHODOLOGY TO UPDATE ECONOMIC VALUES

The values developed in this report are expected to change with the passage of time primarily because of price and income level changes and, to a lesser extent, improvements resulting from future theoretical and empirical research. This report will be revised periodically to account for such changes and advancements. Between revisions, users may desire to adjust the 1987 base year values (1988 base year values in a few cases as indicated) to future year dollars based on the recommendations outlined in this section.

A. Value of Time in Air Travel

It is recommended that the hourly earnings rates of "typical" business and non-business air travelers be maintained as the basis for valuing the time of air travelers. This rate may be adjusted to future year dollars by the GNP Implicit Price Deflator for Total Personal Consumption Expenditures. Expressed in another way,

$$(IPD_f/IPD_b) \times T_b = \text{Updated Value of Time of Air Travelers}$$

were IPD_f and IPD_b are the GNP Implicit Price Deflators for Total Personal Consumption Expenditures of the future year and base year, respectively, and T_b is the value of time of business, non-business, or overall average air travelers in the base year (1987).

Considering the imprecise art of valuing time, it is recommended that future updated values be rounded to the nearest $.50 to avoid specious accuracy.

B. Value of a Statistical Life

It is suggested that the average socially rational valuation of a statistical life be updated using the GNP Implicit Price Deflator for Total Personal Consumption Expenditures (the *Economic Report of the President* is a convenient yearly source for this index, the *Survey of Current Business* provides more frequent updates). The rationale for the selection of this price index is as follows:

1. The private willingness-to-pay estimates are based upon individual assessments which in turn are based upon income, consumption of a wide variety of goods and services in the economy, and the consumption of other non-pecuniary activities. The resulting monetary values probably closely correspond with the typical mix of goods and services available in the economy.

2. The other elements of the valuation of a statistical life are expenses or income measures which should increase in approximate proportion to economy-wide inflation.

Expressed in another way,

$$(IPD_f/IPD_b) \times L_b = \text{Updated Average Socially Rational Valuation of a Statistical Life}$$

where IPD_f and IPD_b are the GNP Implicit Price Deflators for Total Personal Consumption Expenditures of the future and base year, respectively, and L_b is the average socially rational valuation of a statistical life in the base year (1987).

To avoid specious accuracy, it is recommended that adjusted values of life be rounded to the nearest $10,000.

C. Unit Costs of Statistical Aviation Injuries

The average socially rational investment to prevent an injury within an AIS level (including special injury categories) is made up of a number of components: individual willingness-to-pay and foregone taxes (just lost productivity for AIS 1, minor injuries), medical costs, and legal and administrative costs. It is recommended that these values be updated using the GNP Implicit Price Deflator for Total Personal Consumption Expenditures for all cost categories except medical costs. The Consumer Price Index for All Medical Care is the recommended index to be used to update the medical cost component. Expressed in another way,

$$((IPD_f/IPD_b) \times NonMC_b) + ((CPI\text{-}M_f/CPI\text{-}M_b) \times MC_b) = \text{Updated Socially Rational Investment to Prevent an Injury}$$

where IPD_f and IPD_b are the GNP Implicit Price Deflators for Total Personal Consumption Expenditures for the future and base year, $NonMC_b$ is the total average cost for all non-medical cost categories in the base year, $CPI\text{-}M_f$ and $CPI\text{-}M_b$ are the Consumer Price Indices for All Medical Care for the future and base years, and MC_b is the average medical-related cost for the base year. The base year is 1987 in all cases.

It should be noted that medical costs, lost functioning years, and recovery times (and the resulting foregone taxes) for AIS 4 and 5 accidents are subject to revision as basic statistical knowledge related to these accidents continues to improve. This is particularly true for spinal, head and burn injuries.

To avoid specious accuracy, it is recommended that updated injury costs be rounded to the nearest $100 for values less than $10,000, to the nearest $1,000 for values between $10,000 and $100,000, and to the nearest $10,000 for values greater than $100,000.

D. Aircraft Capacity and Utilization Factors

These values represent the physical makeup and operations of the fleet. No economic index can be used to adjust these factors over time. The procedures and sources described in Section 4 can be used to obtain updates of capacity and utilization factors.

E. Aircraft Variable Operating Costs

Aircraft variable operating costs, as defined and developed in Section 5, consist of fuel, oil, direct maintenance of airframe, avionics and engine, plus flight crew salaries and wages for air carrier, air taxi and air commuter operators. Other costs of a semi-variable or fixed nature are considered irrelevant for the purposes of measuring the cost of delay or the savings of reduced operating time. The costs of aviation fuel and oil may be readily adjusted to future year dollar levels by reference to published fuel price indices (e.g., such as those provided in annual editions of FAA Aviation Forecasts). The GNP Implicit Price Deflator for Total Personal Consumption Expenditures may be thought of as an appropriate means by which to adjust direct maintenance costs and allowances for flight crew salaries. Expressed another way:

$$((F_f/F_b) \times FO_b) + ((IPD_f/IPD_b) \times M_b) = \text{Adjusted Aircraft Variable Operating Costs}$$

where F_f and F_b are the prices of aviation gas/jet fuel per gallon in the future year and base year, IPD_f and IPD_b are the GNP Implicit Price Deflators for Total Personal Consumption Expenditures for the future year and base year, and FO_b and M_b are the fuel and oil and maintenance costs, respectively, per hour of aircraft operation in the base year. It is recommended that updated variable operating costs be rounded to the nearest dollar.

F. Unit Replacement and Restoration Costs of Damaged Aircraft

In the absence of a more specific index, it is suggested that the Department of Labor Bureau of Labor Statistics' Producer Price Index for Total Transportation Equipment be used to adjust aircraft replacement and restoration costs to future year dollars. Expressed another way:

$$(PPI\text{-}TE_f/PPI\text{-}TE_b) \times (REP_b \text{ or } RES_b) = \text{Adjusted Unit Replacement/Restoration Cost of a Damaged Aircraft}$$

where $PPI\text{-}TE_f$ and $PPI\text{-}TE_b$ are the Producer Price Indices for Total Tranportation Equipment for the future year and base year, REP_b is the unit replacement cost of a destroyed aircraft in the base year, and RES_b is the unit restoration cost of a substantially damaged aircraft in the base year.

To avoid specious accuracy, it is recommended that adjusted aircraft replacement and restoration costs be rounded to the nearest $1,000 for values

less than $1,000,000 and to the nearest $10,000 for values greater than $1,000,000.

G. Models to Estimate Weight Penalties Due to Regulatory Changes

These models calculate new results based on current and projected fuel price levels. As such these estimates are updated every time the model is run.

H. Probabilities of Third Party Damage

Updating these figures will require runs of the NTSB database in the future. Note that new runs should not use data before 1982 because these are incompatible with data after 1982 due to NTSB changes in accident reports and the computer system used to develop the data.

SECTION 10: ALTERNATE AND APPENDIX TABLES

This section contains alternate and appendix tables referred to in Sections 3 through 9. The first group of tables present results using alternate methodologies to those recommended in Section 3. The remainder provide additional data in support of recommended results arrived at in Sections 4 through 9.

Alternate Table 9-B

Unit Cost of AIS Level 2 (Moderate) Aviation Injuries, Human Capital Approach ($1987)

FAA User Group	Productivity Losses	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
Air Carrier				
Domestic Pass.	$4,027	$1,918	$1,884	75.4%
Int'l Pass.	5,818	1,918	1,884	4.8%
Commuter	4,027	1,918	1,884	5.1%
GA Piston	5,940	1,918	1,884	9.8%
GA Turbine	21,958	1,918	1,884	3.2%
Rotorcraft	11,724	1,918	1,884	1.1%
Air Taxi	8,230	1,918	1,884	0.6%
Government	3,908	1,918	1,884	0.0%[d]
Military	3,126	1,918	1,884	0.0%[d]
Weighted Average:	$4,984	$1,918	$1,884	

Average Socially Rational Investment, 1987: $8,786

Alternate Table 9-C

Unit Cost of AIS Level 3 (Serious) Aviation Injuries, Human Capital Approach ($1987)

FAA User Group	Productivity Losses	Total Medical Costs[e]	Legal, Court, Other Admin. Costs[f]	Percent of all Aircraft Trips[c]
Air Carrier				
Domestic Pass.	$10,997	$7,871	$2,874	75.4%
Int'l Pass.	15,889	7,871	2,874	4.8%
Commuter	10,997	7,871	2,874	5.1%
GA Piston	16,222	7,871	2,874	9.8%
GA Turbine	59,965	7,871	2,874	3.2%
Rotorcraft	32,017	7,871	2,874	1.1%
Air Taxi	22,476	7,871	2,874	0.6%
Government	10,672	7,871	2,874	0.0%[d]
Military	8,538	7,871	2,874	0.0%[d]
Weighted Average:	$13,611	$7,871	$2,874	

Average Socially Rational Investment, 1987: $24,356

[a] Emergency medical costs, $177 of total for all user groups.
[b] Legal and Court Costs, $1,045 of total for all user groups.
[c] Gellman Research Associates (See Table 9-A)
[d] Insufficient data, probably .1% or less of all trips.
[e] Emergency medical costs, $185 of total for all user groups.
[f] Legal and Court Costs, $2,018 of total for all user groups.

Alternate Table 9-D

Unit Cost of AIS Level 4 (Severe) Aviation Injuries, Human Capital Approach ($1987)

FAA User Group	Productivity Losses	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
Air Carrier				
Domestic Pass.	$108,879	$34,843	$23,784	75.4%
Int'l Pass.	175,313	35,471	23,915	4.8%
Commuter	108,879	34,843	23,784	5.1%
GA Piston	123,473	32,330	22,998	9.8%
GA Turbine	456,428	32,330	22,998	3.2%
Rotorcraft	317,001	34,843	23,784	1.1%
Air Taxi	222,535	34,843	23,784	0.6%
Government	105,667	34,843	23,784	0.0%[d]
Military	113,751	37,670	24,439	0.0%[d]
Weighted Average:	$127,591	$34,546	$23,688	

Average Socially Rational Investment, 1987: $185,825

Alternate Table 9-E

Unit Cost of AIS Level 5 (Critical) Aviation Injuries, Human Capital Approach ($1987)

FAA User Group	Productivity Losses	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[e]	Percent of all Aircraft Trips[c]
Air Carrier				
Domestic Pass.	$285,426	$105,798	$48,625	75.4%
Int'l Pass.	459,580	107,716	48,756	4.8%
Commuter	285,426	105,798	48,625	5.1%
GA Piston	323,683	98,125	47,839	9.8%
GA Turbine	1,196,521	98,125	47,839	3.2%
Rotorcraft	831,014	105,798	48,625	1.1%
Air Taxi	583,372	105,798	48,625	0.6%
Government	277,005	105,798	48,625	0.0%[d]
Military	298,198	114,430	49,279	0.0%[d]
Weighted Average:	$334,479	$104,892	$48,529	

Average Socially Rational Investment, 1987: $487,900

[a] Emergency medical costs, $294 of total for all user groups.
[b] Legal and Court Costs, $15,053 of total for all user groups.
[c] Gellman Research Associates (See Table 9-A)
[d] Insufficient data, probably .1% or less of all trips.
[e] Legal and Court Costs, $39,893 of total for all user groups.

Alternate Table 10-A

Unit Cost of AIS Level 4 (Severe) Spinal Cord Aviation Injuries
Human Capital Approach
($1987)

Degree of Disability/ FAA User Group	Productivity Losses	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
Quadriplegia:				
Air Carrier				
Domestic Pass.	$574,349	$223,492	$23,784	75.4%
Int'l Pass.	846,162	225,049	23,915	4.8%
Commuter	574,349	223,492	23,784	5.1%
GA Piston	826,821	217,264	22,998	9.8%
GA Turbine	3,500,214	217,264	22,998	3.2%
Rotorcraft	1,672,214	223,492	23,784	1.1%
Air Taxi	1,173,895	223,492	23,784	0.6%
Government	557,405	223,492	23,784	0.0%[d]
Military	607,417	230,498	24,439	0.0%[d]
Weighted Average:	$721,440	$222,757	$23,688	
Average Socially Rational Investment, 1987:				$967,885

Degree of Disability/ FAA User Group	Productivity Losses	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
Paraplegia:				
Air Carrier				
Domestic Pass.	$119,813	$142,391	$23,784	75.4%
Int'l Pass.	187,368	143,191	23,915	4.8%
Commuter	119,813	142,391	23,784	5.1%
GA Piston	141,962	139,192	22,998	9.8%
GA Turbine	524,775	139,192	22,998	3.2%
Rotorcraft	348,835	142,391	23,784	1.1%
Air Taxi	244,882	142,391	23,784	0.6%
Government	116,278	142,391	23,784	0.0%[d]
Military	113,943	145,990	24,439	0.0%[d]
Weighted Average:	$141,455	$142,013	$23,688	
Average Socially Rational Investment, 1987:				$307,156

[a] Emergency medical costs, $294 of total for all user groups.
[b] Legal and Court Costs, $15,053 of total for all user groups.
[c] Gellman Research Associates (See Table 9-A)
[d] Insufficient data, probably .1% or less of all trips.

Alternate Table 10-B

Unit Cost of AIS Level 5 (Critical) Spinal Cord Aviation Injuries
Human Capital Approach
($1987)

Degree of Disability/ FAA User Group	Productivity Losses	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
Quadriplegia:				
Air Carrier				
Domestic Pass.	$574,349	$309,922	$48,625	75.4%
Int'l Pass.	846,162	312,236	48,756	4.8%
Commuter	574,349	309,922	48,625	5.1%
GA Piston	826,821	300,666	47,839	9.8%
GA Turbine	3,500,214	300,666	47,839	3.2%
Rotorcraft	1,672,214	309,922	48,625	1.1%
Air Taxi	1,173,895	309,922	48,625	0.6%
Government	557,405	309,922	48,625	0.0%[d]
Military	607,417	320,336	49,279	0.0%[d]
Weighted Average:	$721,440	$308,830	$48,529	
Average Socially Rational Investment, 1987:				$1,078,799
Paraplegia:				
Air Carrier				
Domestic Pass.	$311,975	$187,820	$48,625	75.4%
Int'l Pass.	502,639	189,174	48,756	4.8%
Commuter	311,975	187,820	48,625	5.1%
GA Piston	354,009	182,402	47,839	9.8%
GA Turbine	1,308,624	182,402	47,839	3.2%
Rotorcraft	908,314	187,820	48,625	1.1%
Air Taxi	637,636	187,820	48,625	0.6%
Government	302,771	187,820	48,625	0.0%[d]
Military	326,136	193,914	49,279	0.0%[d]
Weighted Average:	$365,653	$187,180	$48,529	
Average Socially Rational Investment, 1987:				$601,362

[a] Emergency medical costs, $294 of total for all user groups.
[b] Legal and Court Costs, $39,893 of total for all user groups.
[c] Gellman Research Associates (See Table 9-A)
[d] Insufficient data, probably .1% or less of all trips.

Alternate Table 10-C

Unit Cost of AIS Level 4 (Severe) Head Aviation Injuries
Human Capital Approach
($1987)

Degree of Disability/ FAA User Group	Productivity Losses	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
Total Disability:				
Air Carrier				
Domestic Pass.	$574,349	$412,404	$23,784	75.4%
Int'l Pass.	846,162	417,938	23,915	4.8%
Commuter	574,349	412,404	23,784	5.1%
GA Piston	826,821	390,265	22,998	9.8%
GA Turbine	3,500,214	390,265	22,998	3.2%
Rotorcraft	1,672,214	412,404	23,784	1.1%
Air Taxi	1,173,895	412,404	23,784	0.6%
Government	557,405	412,404	23,784	0.0%[d]
Military	607,417	437,309	24,439	0.0%[d]
Weighted Average:	$721,440	$409,791	$23,688	

Average Socially Rational Investment, 1987: $1,154,919

Degree of Disability/ FAA User Group	Productivity Losses	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
Partial Disability:				
Air Carrier				
Domestic Pass.	$100,701	$49,348	$23,784	75.4%
Int'l Pass.	162,244	49,774	23,915	4.8%
Commuter	100,701	49,348	23,784	5.1%
GA Piston	114,269	47,642	22,998	9.8%
GA Turbine	422,404	47,642	22,998	3.2%
Rotorcraft	293,190	49,348	23,784	1.1%
Air Taxi	205,819	49,348	23,784	0.6%
Government	97,730	49,348	23,784	0.0%[d]
Military	105,272	51,267	24,439	0.0%[d]
Weighted Average:	$118,027	$49,146	$23,688	

Average Socially Rational Investment, 1987: $190,862

[a] Emergency medical costs, $294 of total for all user groups.
[b] Legal and Court Costs, $15,053 of total for all user groups.
[c] Gellman Research Associates (See Table 9-A)
[d] Insufficient data, probably .1% or less of all trips.

Alternate Table 10-D

Unit Cost of AIS Level 5 (Critical) Head Aviation Injuries
Human Capital Approach
($19[illegible])

Degree of Disability/ FAA User Group	Productivity Losses	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
Total Disability:				
Air Carrier				
Domestic Pass.	$574,349	$461,618	$48,625	75.4%
Int'l Pass.	846,162	467,504	48,756	4.8%
Commuter	574,349	461,618	48,625	5.1%
GA Piston	826,821	438,072	47,839	9.8%
GA Turbine	3,500,214	438,072	47,839	3.2%
Rotorcraft	1,672,214	461,618	48,625	1.1%
Air Taxi	1,173,895	461,618	48,625	0.6%
Government	557,405	461,618	48,625	0.0%[d]
Military	607,417	488,107	49,279	0.0%[d]
Weighted Average:	$721,440	$458,839	$48,529	
Average Socially Rational Investment, 1987:				$1,288,808
Partial Disability:				
Air Carrier				
Domestic Pass.	$187,580	$133,648	$48,625	75.4%
Int'l Pass.	302,219	134,831	48,756	4.8%
Commuter	187,580	133,648	48,625	5.1%
GA Piston	212,854	128,913	47,839	9.8%
GA Turbine	786,831	128,913	47,839	3.2%
Rotorcraft	546,138	133,648	48,625	1.1%
Air Taxi	383,389	133,648	48,625	0.6%
Government	182,046	133,648	48,625	0.0%[d]
Military	196,094	138,974	49,279	0.0%[d]
Weighted Average:	$219,855	$133,089	$48,529	
Average Socially Rational Investment, 1987:				$401,472

[a] Emergency medical costs, $294 of total for all user groups.
[b] Legal and Court Costs, $39,893 of total for all user groups.
[c] Gellman Research Associates (See Table 9-A)
[d] Insufficient data, probably .1% or less of all trips.

<u>Alternate Table 10-E</u>

Unit Cost of AIS Level 4 and Level 5 Burn Aviation Injuries
Human Capital Approach
($1987)

Level of Injury FAA User Group	Productivity Losses	Total Medical Costs[a]	Legal, Court, Other Admin. Costs[b]	Percent of all Aircraft Trips[c]
<u>AIS Level 4 Burns:</u>				
Air Carrier				
Domestic Pass.	$100,701	$49,348	$23,784	75.4%
Int'l Pass.	162,244	49,774	23,915	4.8%
Commuter	100,701	49,348	23,784	5.1%
GA Piston	114,269	47,642	22,998	9.8%
GA Turbine	422,404	47,642	22,998	3.2%
Rotorcraft	293,190	49,348	23,784	1.1%
Air Taxi	205,819	49,348	23,784	0.6%
Government	97,730	49,348	23,784	0.0%[d]
Military	105,272	51,267	24,439	0.0%[d]
Weighted Average:	$118,027	$49,146	$23,688	
Average Socially Rational Investment, 1987:				<u>$190,862</u>
<u>AIS Level 5 Burns:</u>				
Air Carrier				
Domestic Pass.	$187,580	$133,648	$48,625	75.4%
Int'l Pass.	302,219	134,831	48,756	4.8%
Commuter	187,580	133,648	48,625	5.1%
GA Piston	212,854	128,913	47,839	9.8%
GA Turbine	786,831	128,913	47,839	3.2%
Rotorcraft	546,138	133,648	48,625	1.1%
Air Taxi	383,389	133,648	48,625	0.6%
Government	182,046	133,648	48,625	0.0%[d]
Military	196,094	138,974	49,279	0.0%[d]
Weighted Average:	$219,855	$133,0[illegible]	$48,529	
Average Socially Rational Investment, 1987:				<u>$401,472</u>

[a] Emergency medical costs, $294 of total for all user groups.
[b] Legal and Court Costs, $15,053 of total for all user groups.
[c] Gellman Research Associates (See Table 9-A)
[d] Insufficient data, probably .1% or less of all trips.

Appendix Table 1

Large Air Carrier Aircraft Capacity and Utilization - CY 1987
(through 2nd Quarter 1987)

Average Equipment Type and Make/Model		Model Factors
Turbofan, 4-Engine Wide Body		
BOEING 747	Avg Seats	369.2
	Avg Cargo (tons)	57.2
	Pass. Load (%)	63.5
	Cargo Load (%)	59.8
	Daily Ut. (hrs.)	10.3
	Avg. MPH	508.5
Turbofan, 4-Engine Narrow Body		
BAE 146	Avg Seats	85.0
	Avg Cargo (tons)	9.8
	Pass. Load (%)	60.4
	Cargo Load (%)	50.7
	Daily Ut. (hrs.)	7.9
	Avg. MPH	342.0
MDD DC8	Avg Seats	201.9
	Avg Cargo (tons)	26.5
	Pass. Load (%)	66.9
	Cargo Load (%)	54.4
	Daily Ut. (hrs.)	8.9
	Avg. MPH	461.0
Turbofan, 3-Engine Wide Body		
MDD DC10	Avg Seats	275.4
	Avg Cargo (tons)	39.9
	Pass. Load (%)	68.5
	Cargo Load (%)	57.8
	Daily Ut. (hrs.)	9.4
	Avg. MPH	490.0
LOCKHEED L1011	Avg Seats	283.7
	Avg Cargo (tons)	36.7
	Pass. Load (%)	62.5
	Cargo Load (%)	56.5
	Daily Ut. (hrs.)	9.0
	Avg. MPH	497.0

Appendix Table 1 (Continued)

Equipment Type and Make/Model		Model Average Factors
Turbofan, 3-Engine Narrow Body		
BOEING 727	Avg Seats	148.8
	Avg Cargo (tons)	18.4
	Pass. Load (%)	61.4
	Cargo Load (%)	53.0
	Daily Ut. (hrs.)	8.3
	Avg. MPH	428.5
Turbofan, 2-Engine Wide Body		
AIRBUS A300	Avg Seats	255.7
	Avg Cargo (tons)	37.2
	Pass. Load (%)	65.7
	Cargo Load (%)	56.3
	Daily Ut. (hrs.)	8.7
	Avg. MPH	445.0
BOEING 767	Avg Seats	196.3
	Avg Cargo (tons)	30.6
	Pass. Load (%)	65.6
	Cargo Load (%)	48.2
	Daily Ut. (hrs.)	10.5
	Avg. MPH	469.0
Turbofan, 2-Engine Narrow Body		
BOEING 737	Avg Seats	132.0
	Avg Cargo (tons)	14.7
	Pass. Load (%)	58.4
	Cargo Load (%)	49.5
	Daily Ut. (hrs.)	8.1
	Avg. MPH	391.5
BOEING 757	Avg Seats	185.7
	Avg Cargo (tons)	23.0
	Pass. Load (%)	63.1
	Cargo Load (%)	49.1
	Daily Ut. (hrs.)	9.2
	Avg. MPH	454.0
MDD DC9	Avg Seats	102.7
	Avg Cargo (tons)	12.5
	Pass. Load (%)	60.2
	Cargo Load (%)	51.6
	Daily Ut. (hrs.)	7.2
	Avg. MPH	383.5
MDD MD80	Avg Seats	143.8
	Avg Cargo (tons)	18.1
	Pass. Load (%)	60.1
	Cargo Load (%)	49.5
	Daily Ut. (hrs.)	9.0
	Avg. MPH	424.5

Appendix Table 2

General Aviation Aircraft Capacity and Utilization Factors
by Make and Model - 1987

Make/Model	FAA-APO Type	Seating Capacity	Seats Occupied	Useful Load (lbs)
AIRCOUPE415	1	2	91.7%	600
BELLANCA8	1	3	51.8%	550
BOEING75	1	2	80.8%	500
CESSN120	1	2	60.0%	600
CESSN140	1	2	79.2%	650
CESSN150	1	2	69.1%	500
CESSN188	1	1	100.0%	1662
GRTLK2T1	1	2	80.0%	600
GRUM164	1	1	100.0%	1519
GULSTAA1	1	2	71.5%	585
LUSCOM8	1	2	75.0%	500
PIPER18	1	2	81.7%	773
PIPER25	1	1	100.0%	1294
PIPER36	1	1	100.0%	2111
PIPER38	1	2	79.2%	500
PIPERJ3	1	2	62.5%	400
VARG2150	1	2	75.0%	700
AERONCA15	2	4	43.8%	800
AYRESS2	2	1	100.0%	2300
BEECH23	2	4	48.3%	1025
BEECH33	2	4	66.5%	1263
BEECH35	2	4	50.6%	1169
BEECH36	2	6	46.4%	1463
BELLANCA17	2	4	34.4%	1116
BELLANCA1419	2	4	34.4%	1163
BELLANCA7	2	3	51.0%	500
CESSN170	2	4	45.8%	1000
CESSN172	2	4	37.9%	942
CESSN175	2	4	56.3%	1000
CESSN177	2	4	44.7%	977
CESSN180	2	4	53.4%	1114
CESSN182	2	4	53.4%	1160
CESSN185	2	6	37.1%	1634
CESSN195	2	5	30.0%	1300
CESSN205	2	6	41.7%	1500
CESSN206	2	6	36.4%	1659
CESSN207	2	6	46.3%	1800
CESSN210	2	6	36.8%	1454
GULSTAA5	2	4	49.0%	910
MAULEM4	2	4	45.0%	900
MAULEM5	2	4	45.0%	922
MAULEM6	2	4	45.0%	900
MOONEY20	2	4	51.4%	1019
NAVION	2	5	31.4%	954

Appendix Table 2 (Continued)

Make/Model	FAA-APO Type	Seating Capacity	Seats Occupied	Useful Load (lbs)
PIPER22	2	4	46.6%	795
PIPER24	2	4	53.9%	1157
PIPER28	2	4	55.5%	1151
PIPER32	2	6	42.5%	1601
ROCKWELL112	2	4	37.5%	993
BEECH18	3	10	22.0%	3367
BEECH50	3	6	33.3%	2150
BEECH55	3	6	31.6%	2134
BEECH56	3	6	33.3%	2300
BEECH58	3	6	42.9%	2147
BEECH60	3	6	25.0%	2363
BEECH95	3	6	33.3%	1700
CESSN310	3	5	44.3%	2021
CESSN320	3	6	38.9%	1968
CESSN337	3	6	39.6%	1590
CESSN340	3	6	37.5%	2200
PIPER23	3	5	53.0%	1865
PIPER30	3	4	57.5%	1400
PIPER31	3	8	50.0%	2536
PIPER44	3	4	50.0%	1400
PIPER600	3	6	26.4%	1995
BEECH65	4	9	47.2%	3033
BEECH80	4	11	36.4%	3550
CESSN401	4	8	37.5%	2600
CESSN402	4	9	35.4%	2576
CESSN404	4	8	56.3%	3400
CESSN411	4	8	31.3%	2700
CESSN414	4	8	37.5%	2200
CESSN421	4	8	40.5%	2911
PIPER34	4	7	33.3%	1741
ROCKWELL500	4	7	30.9%	2211
ROCKWELL560	4	7	30.9%	1982
ROCKWELL680	4	7	35.7%	2900
BEECH100	6	11	31.8%	4742
BEECH200	6	11	31.8%	5000
BEECH90	6	10	26.7%	3941
CESSN441	6	10	35.0%	4200
MITSUBISHI2	6	10	31.8%	3985
PIPER31T	6	8	50.0%	4000
ROCKWELL680T	6	11	22.7%	3757
ROCKWELL690T	6	11	25.0%	3833
SWER226	6	12	45.8%	4855
SWER227	6	12	45.8%	5800
SWER26	6	8	68.8%	3736
DEHAVILL6	7	22	50.0%	4570
EMBRAER110	7	20	55.0%	7000

Appendix Table 2 (Continued)

Make/Model	FAA-APO Type	Seating Capacity	Seats Occupied	Useful Load (lbs)
CESSN500	9	8	37.5%	5080
CESSN650	9	12	25.0%	8986
FALCON10	9	7	42.9%	8000
FALCON20	9	10	30.0%	10900
HWKDH125	9	10	30.0%	10000
ISRL1121	9	10	30.0%	7000
ISRL1124	9	10	30.0%	10300
LEAR23	9	8	37.5%	5800
LEAR24	9	8	37.5%	6250
LEAR25	9	10	30.0%	8000
LEAR35	9	10	30.0%	7715
LEAR55	9	10	30.0%	7608
NAROCKWELL265	9	6	50.0%	10200
BELL47	11	3	58.1%	1100
ENSTROMF28	11	3	62.5%	800
HILLER12	11	4	31.3%	1300
HUGHES269SCH	11	3	63.9%	965
ROBINSONR22	11	2	85.3%	500
AEROSPAT316	12	7	54.8%	2400
AEROSPAT350	12	6	63.9%	2300
AEROSPAT355	12	7	54.8%	2452
AGUSTA109	12	8	50.0%	2800
BELL204	12	6	83.3%	3900
BELL205	12	15	33.3%	5200
BELL206	12	5	55.0%	1800
BELL212	12	15	33.3%	5200
BELL214	12	18	27.8%	7500
BELL222	12	10	40.0%	3300
BELL412	12	15	33.3%	5500
HUGHES369MDD	12	6	35.7%	2074
SIKORSKY76	12	14	35.7%	4200

Appendix Table 3

Air Carrier Aircraft Variable Operating Costs - CY 1987
(through 2nd quarter 1987)

Equipment Type and Make/Model		Model Average V.O.C.
Turbofan, 4-Engine Wide Body		
BOE747	Crew	$811.67
	Fuel & Oil	1,875.57
	Maintenance	708.64
Turbofan, 4-Engine Narrow Body		
BAE146	Crew	247.30
	Fuel & Oil	370.40
	Maintenance	400.50
DC8	Crew	598.50
	Fuel & Oil	842.50
	Maintenance	305.70
Turbofan, 3-Engine Wide Body		
DC10	Crew	630.03
	Fuel & Oil	1,203.18
	Maintenance	607.09
L1011	Crew	674.77
	Fuel & Oil	1,270.10
	Maintenance	630.11
Turbofan, 3-Engine Narrow Body		
BOE727	Crew	460.51
	Fuel & Oil	673.51
	Maintenance	221.42
Turbofan, 2-Engine Wide Body		
A300	Crew	496.94
	Fuel & Oil	947.33
	Maintenance	638.40
BOE767	Crew	503.74
	Fuel & Oil	713.82
	Maintenance	205.84

Appendix Table 3 (Continued)

Equipment Type and Make/Model		Model Average V.O.C.
Turbofan, 2-Engine Narrow Body		
BOE737	Crew	$332.69
	Fuel & Oil	418.55
	Maintenance	157.11
BOE757	Crew	437.10
	Fuel & Oil	528.51
	Maintenance	207.35
DC9	Crew	332.80
	Fuel & Oil	423.46
	Maintenance	235.90
MD80	Crew	281.64
	Fuel & Oil	476.67
	Maintenance	169.71
Turboprop, 4-Engine		
DHC-7	Crew	120.55
	Fuel & Oil	123.15
	Maintenance	254.29
L-188	Crew	203.40
	Fuel & Oil	185.60
	Maintenance	645.83
Turboprop, 2-Engine, 20+ Seats		
ATR42	Crew	176.21
	Fuel & Oil	100.70
	Maintenance	114.81
DHC-6	Crew	69.41
	Fuel & Oil	58.49
	Maintenance	92.49
EMB120	Crew	122.25
	Fuel & Oil	94.95
	Maintenance	75.47
FAIR F-27	Crew	126.80
	Fuel & Oil	138.83
	Maintenance	114.74
GULFST. G159	Crew	88.27
	Fuel & Oil	148.63
	Maintenance	138.77
METRO II	Crew	69.57
	Fuel & Oil	67.46
	Maintenance	112.53
SAAB340	Crew	131.99
	Fuel & Oil	107.85
	Maintenance	178.92

Appendix Table 3 (Continued)

Equipment Type and Make/Model		Model Average V.O.C.
SHORT330	Crew	$69.45
	Fuel & Oil	105.34
	Maintenance	114.01
SHORT360	Crew	83.53
	Fuel & Oil	103.85
	Maintenance	121.25
Turboprop, 2-Engine, Less than 20 Seat Commuter		
BEECH99	Crew	68.00
	Fuel & Oil	71.81
	Maintenance	80.84
BEECH1900	Crew	120.19
	Fuel & Oil	141.70
	Maintenance	124.63
EMB110	Crew	59.00
	Fuel & Oil	69.74
	Maintenance	98.33
Piston, Multiengine		
CESSNA 402	Crew	38.13
	Fuel & Oil	44.41
	Maintenance	46.22
Turboprop, 2-Engine, ALASKA		
BEECH 90	Crew	178.20
	Fuel & Oil	90.30
	Maintenance	51.20
BEECH1900	Crew	70.10
	Fuel & Oil	98.00
	Maintenance	59.60
CV 580	Crew	75.00
	Fuel & Oil	313.90
	Maintenance	338.90
DHC-6	Crew	67.80
	Fuel & Oil	79.50
	Maintenance	128.40

Appendix Table 3 (Continued)

Equipment Type and Make/Model		Model Average V.O.C.
Piston, All Types, ALASKA		
CESSNA	Crew	42.00
207	Fuel & Oil	44.10
	Maintenance	35.20
DOUGLAS	Crew	108.50
DC3	Fuel & Oil	198.40
	Maintenance	203.00
PIPER	Crew	46.80
PA31	Fuel & Oil	95.00
	Maintenance	63.20

Appendix Table 4

General Aviation Aircraft Variable Operating Costs
by Make and Model - 1987
(excluding crew costs, see Tables 22 and 23)

Make/Model	FAA-APO Type	Maintenance	Fuel & Oil	Total V.O.C.
AIRCOUPE415	1	$4.05	$15.75	$19.80
BELLANCA8	1	12.33	16.45	28.78
BOEING75	1	21.24	25.38	46.61
CESSN120	1	4.05	8.75	12.80
CESSN140	1	4.05	9.28	13.33
CESSN150	1	5.96	10.33	16.29
CESSN188	1	31.42	32.03	63.45
GRTLK2T1	1	16.14	18.03	34.17
GRUM164	1	50.52	49.18	99.69
GULSTAA1	1	6.98	11.20	18.18
LUSCOM8	1	4.69	8.40	13.09
PIPER18	1	12.33	13.48	25.80
PIPER25	1	23.15	26.08	49.22
PIPER36	1	31.42	36.05	67.47
PIPER38	1	7.49	10.68	18.16
PIPERJ3	1	4.00	7.88	11.88
VARG2150	1	12.33	13.83	26.15
AERONCA15	2	11.69	15.58	27.26
AYRESS2	2	69.61	55.48	125.09
BEECH23	2	16.14	16.45	32.59
BEECH33	2	29.51	23.10	52.61
BEECH35	2	29.51	22.40	51.91
BEECH36	2	29.51	26.60	56.11
BELLANCA17	2	31.42	24.50	55.92
BELLANCA1419	2	22.51	21.35	43.86
BELLANCA7	2	12.33	11.20	23.53
CESSN170	2	11.69	14.18	25.86
CESSN172	2	12.33	14.88	27.20
CESSN175	2	15.51	16.98	32.48
CESSN177	2	16.14	16.80	32.94
CESSN180	2	22.51	21.70	44.21
CESSN182	2	22.51	22.23	44.73
CESSN185	2	31.42	25.20	56.62
CESSN195	2	28.24	24.50	52.74
CESSN205	2	26.33	21.00	47.33
CESSN206	2	31.42	26.60	58.02
CESSN207	2	31.42	27.48	58.90
CESSN210	2	31.42	26.60	58.02
GULSTAA5	2	16.14	14.70	30.84
MAULEM4	2	21.24	17.15	38.39
MAULEM5	2	23.15	20.13	43.27

Appendix Table 4 (Continued)

Make/Model	FA-APO Type	Maintenance	Fuel & Oil	Total V.O.C.
MAULEM6	2	23.15	21.00	$44.15
MOONEY20	2	16.14	17.33	33.47
NAVION	2	29.51	20.30	49.81
PIPER22	2	12.33	14.18	26.50
PIPER24	2	16.14	21.88	38.02
PIPER28	2	23.15	16.63	39.77
PIPER32	2	31.42	26.78	58.20
ROCKWELL112	2	19.96	21.88	41.84
BEECH18	3	107.80	81.90	189.70
BEECH50	3	79.79	50.40	130.19
BEECH55	3	59.43	46.38	105.80
BEECH56	3	89.98	65.10	155.08
BEECH58	3	65.79	56.53	122.32
BEECH60	3	89.98	74.90	164.88
BEECH95	3	39.06	34.48	73.53
CESSN310	3	59.43	46.20	105.63
CESSN320	3	59.43	48.48	107.90
CESSN337	3	46.70	36.40	83.10
CESSN340	3	72.16	58.98	131.13
PIPER23	3	56.88	41.13	98.01
PIPER30	3	33.97	27.83	61.79
PIPER31	3	72.16	65.63	137.78
PIPER44	3	39.06	33.43	72.48
PIPER600	3	67.06	55.83	122.89
BEECH65	4	79.79	67.03	146.82
BEECH80	4	89.98	72.10	162.08
CESSN401	4	69.61	56.35	125.96
CESSN402	4	69.61	59.15	128.76
CESSN404	4	88.71	78.23	166.93
CESSN411	4	79.79	62.30	142.09
CESSN414	4	72.16	60.90	133.06
CESSN421	4	88.71	77.18	165.88
PIPER34	4	44.15	40.60	84.75
ROCKWELL500	4	56.88	53.20	110.08
ROCKWELL560	4	82.34	51.45	133.79
ROCKWELL680	4	79.79	75.08	154.87
BEECH100	6	98.65	132.32	230.97
BEECH200	6	98.65	139.84	238.49
BEECH90	6	98.65	117.44	216.09
CESSN441	6	98.65	110.24	208.89
MITSUB2	6	98.65	123.84	222.49
PIPER31T	6	98.65	113.76	212.41
ROCKWELL680T	6	98.65	109.76	208.41
ROCKWELL690T	6	98.65	119.68	218.33

Appendix Table 4 (Continued)

Make/Model	FAA-APO Type	Maintenance	Fuel & Oil	Total V.O.C.
SWER226	6	98.65	138.24	$236.89
SWER227	6	98.65	112.00	210.65
SWER26	6	98.65	113.44	212.09
DEHAVILL6	7	98.65	150.40	249.05
EMBRAER110	7	98.65	126.40	225.05
CESSN500	9	203.00	264.32	467.32
CESSN650	9	203.00	356.80	559.80
FALCON10	9	203.00	360.16	563.16
FALCON20	9	203.00	584.80	787.80
HWKDH125	9	203.00	413.28	616.28
ISRL1121	9	203.00	446.56	649.56
ISRL1124	9	203.00	365.76	568.76
LEAR23	9	203.00	399.04	602.04
LEAR24	9	203.00	384.96	587.96
LEAR25	9	203.00	446.88	649.88
LEAR35	9	203.00	292.16	495.16
LEAR55	9	203.00	318.40	521.40
RKWLNA265	9	203.00	484.80	687.80
BELL47	11	35.00	28.00	63.00
ENSTROMF28	11	35.00	22.75	57.75
HILLER12	11	35.00	31.50	66.50
HUGHES269SCH	11	35.00	19.25	54.25
ROBINSONR22	11	35.00	14.00	49.00
AEROSPAT316	12	71.00	94.40	165.40
AEROSPAT350	12	71.00	60.80	131.80
AEROSPAT355	12	71.00	88.00	159.00
AGUSTA109	12	71.00	91.20	162.20
BELL204	12	71.00	115.20	186.20
BELL205	12	71.00	144.00	215.00
BELL206	12	71.00	44.80	115.80
BELL212	12	71.00	152.00	223.00
BELL214	12	71.00	209.60	280.60
BELL222	12	71.00	120.00	191.00
BELL412	12	71.00	166.40	237.40
HUGHES369MDD	12	71.00	41.60	112.60
SIKORSKY76	12	71.00	144.00	215.00

Appendix Table 5

MILITARY AIRCRAFT VARIABLE OPERATING COSTS 1988-1992
(constant 1988 dollars)

Equipment Type and Make/Model	V.O.C. Per Flight Hour Fuel&Oil	Maintenance	Total
TURBOJET/FAN - MULTIENGINE			
Boeing B-52	$2,733	$1,297	$4,030
Boeing C135	1,395	430	1,825
Boeing E3	1,571	573	2,144
Boeing E4	3,307	158	3,465
Boeing E6	1,164	573	1,737
Boeing KC135A-Q	1,403	416	1,819
Boeing KC135R	1,164	339	1,503
Lockheed C5A	2,571	1,041	3,612
Lockheed C5B	2,571	926	3,497
Lockheed C141	1,498	360	1,858
MDD C17	1,164	430	1,594
MDD KC10	1,953	807	2,760
Rockwell B1	2,612	2,255	4,867
TURBOJET/FAN - OTHER (EXCLUDING FIGHTER/ATTACK)			
Boeing T43 (737)	598	174	772
C20/21	180	370	550
Cessna A/T-37	136	42	178
Cessna T47 (500)	122	210	332
Lockheed S3	257	1,593	1,850
MDD A/T-4	280	402	682
MDD C9	729	193	922
Northrop T38	293	92	385
Rockwell T2	250	292	542
TURBOJET/FAN - ATTACK-FIGHTER			
Fairchild A10	459	297	756
GD F16A&B	621	494	1,115
GD F16 ADS-D	608	494	1,102
GD F111	1,225	1,817	3,042
Grumman A6	660	1,633	2,293
Grumman F14	777	2,298	3,075
MDD AV-8B	500	1,193	1,693
MDD F4	1,351	1,089	2,440
MDD F15A-D	1,172	1,300	2,472
MDD F15E	1,695	1,300	2,995
MDD F18	467	1,445	1,912
Northrop F5	443	239	682
Vought A7	1,601	694	2,295

Appendix Table 5 (Continued)

Equipment Type and Make/Model	V.O.C. Per Flight Hour		
	Fuel&Oil	Maintenance	Total
TURBOPROP			
Beech C12	$74	$133	$207
Beech T34C	40	150	190
Beech T44	80	133	213
Beech U21	80	110	190
Convair C131	1,500	254	1,754
DeHav DHC6-300	88	98	186
Grumman C1	190	777	967
Grumman C2	238	831	1,069
Grumman E2C	250	1,019	1,269
Grumman OV1	82	162	244
Lockheed C130A-E	576	451	1,027
Lock C130 other	632	603	1,235
Lockheed P3A&B	481	805	1,286
Lockheed P3C	481	805	1,286
Rockwell OV-10	73	237	310
PISTON ENGINE			
Beech T42	28	35	63
Beech U8F	38	106	144
Cessna O2	19	40	59
Cessna T41	8	16	24
ROTARY WING			
Bell AH1	63	319	382
Bell AH1T&W	63	319	382
Bell OH58A-C	19	78	97
Bell OH58D	19	32	51
Bell UH-1H	54	102	156
Bell UH-1 M,N,V	54	102	156
Boeing CH46	192	374	566
Boeing CH47	273	574	847
Kamen HH2	72	136	208
MDD AH64	78	595	673
MDD OH6 (500)	14	87	101
Sikorsky SH-3	111	447	558
Sikorsky CH53	234	1,233	1,467
Sikorsky CH53E	234	1,233	1,467
Sikorsky UH60	93	309	402

Appendix Table 6

Air Carrier Aircraft Replacement Cost by Sub-Model - 1987
(in current year $000)

Make/Sub-Model	Population	Bi-Annual Estimate of Aircraft Values 1	Bi-Annual Estimate of Aircraft Values 2	Annual Average	Extension
TWIN ENGINE NARROW BODY					
BAC111-200/300	30	$1750	$1750	$1750	$52500
BAC111-400	15	2000	2000	2000	30000
BOE737-100	20	5000	6000	5500	110000
BOE737-200	141	6500	6500	6500	916500
BOE737-200ADV	286	7500	7500	7500	2145000
BOE737-200C	8	7500	7000	7250	58000
BOE737-200CADV	13	8500	8500	8500	110500
BOE737-300	138	23500	22000	22750	3139500
BOE757-200	93	33800	33300	33550	3120150
DC9-10/15/20	96	3500	3750	3625	348000
DC9-30	324	6500	6750	6625	2146500
DC9-30F	18	7000	7250	7125	128250
DC9-40	3	7500	7750	7625	22875
DC9-50	58	10000	10000	10000	580000
DC9-81	25	15500	16500	16000	400000
DC9-82	143	17500	18500	18000	2574000
DC9-83	4	24500	24500	24500	98000
DC9-88	8	18000	18000	18000	144000
FOK28-1000-3000	23	3760	4600	4180	96140
FOK28-4000/6000	27	8000	10000	9000	243000
TOTAL:	1473				16462915
TYPE AVERAGE:	$11,176				
THREE ENGINE NARROW BODY					
BOE727-100	218	3250	3500	3375	735750
BOE727-100C	115	3750	4500	4125	474375
BOE727-200	243	5000	5000	5000	1215000
BOE727-200ADV	593	6500	6500	6500	3854500
TOTAL:	1169				6279625
TYPE AVERAGE:	$5,372				

Appendix Table 6 (Continued)

Make/Sub-Model	Population	Bi-Annual Estimate of Aircraft Values 1	2	Annual Average	Extension
FOUR ENGINE NARROW BODY					
BAE146-100	3	$12000	$12000	$12000	$36000
BAE146-200	24	17000	15000	16000	384000
BOE707-120B	2	450	450	450	900
BOE707-320B	13	1600	2100	1850	24050
BOE707-320C	20	1750	2600	2175	43500
BOE720B	0	350	350	350	0
DC8-50	3	750	1600	1175	3525
DC8-54/55F	8	1250	1750	1500	12000
DC8-61	2	2250	2500	2375	4750
DC8-62	17	3500	5250	4375	74375
DC8-63	12	6000	8300	7150	85800
DC8-71	46	15000	15000	15000	690000
DC8-72	0	15000	15000	15000	0
DC8-73	22	20000	22500	21250	467500
TOTAL:	172				1826400
TYPE AVERAGE:	$10,619				
TWIN ENGINE WIDE BODY					
A300-B2	2	17500	17500	17500	35000
A300-B4	32	21500	21500	21500	688000
A310	12	40000	30000	35000	420000
BOE767-200	73	40000	35000	37500	2737500
BOE767-300	2	50000	50000	50000	100000
TOTAL:	121				3980500
TYPE AVERAGE:	$32,897				
THREE ENGINE WIDE BODY					
DC10-10	121	20000	22500	21250	2571250
DC10-30	38	32000	35000	33500	1273000
DC10-40	19	17500	17500	17500	332500
L1011-1	114	16000	14000	15000	1710000
L1011-100/200	0	22000	20000	21000	0
TOTAL:	292				5886750
TYPE AVERAGE:	$20,160				
FOUR ENGINE WIDE BODY					
BOE747-100	103	16400	18500	17450	1797350
BOE747-200B	24	28600	30850	29725	713400
BOE747-200C/F	23	37500	40000	38750	891250
BOE747-300	1	100000	100000	100000	100000
BOE747-SP	1	25000	22500	23750	23750
TOTAL:	152				3525750
TYPE AVERAGE:	$23,196				

Appendix Table 6 (Continued)

Make/Sub-Model	Population	Bi-Annual Estimate of Aircraft Values 1	2	Annual Average	Extension
20+ SEAT COMMUTER					
ATR 42	8	$6850	$7400	$7125	$57000
CV580	58	1000	750	875	50750
CV600/640	31	625	500	562.5	17437.5
DHC-6	68	575	575	575	39100
DHC-7	38	3500	3250	3375	128250
DHC-8	29	5700	7750	6725	195025
EMB120	16	5200	5250	5225	83600
FAIR F-27	20	650	500	575	11500
FAIR METROII	119	435	435	435	51765
FH227	7	750	600	675	4725
FOKRF27-100/400	15	1150	1100	1125	16875
FOKRF27-500/600	21	3000	3000	3000	63000
Lock L188	33	1100	900	1000	33000
NORD 262	13	300	300	300	3900
SAAB340	37	6100	6350	6225	230325
SHORT330	107	900	900	900	96300
SHORT360	3	2250	2250	2250	6750
NIHON YS11	36	1000	760	880	31680
TOTAL:	659				1120982.
TYPE AVERAGE:	$1,701				
LESS THAN 20 SEAT COMMUTER					
BEECH99	44	300	300	300	13200
BEECHC-99	51	1350	1350	1350	68850
BEECH1900	61	2250	2000	2125	129625
CASA212	19	750	750	750	14250
EMB110	92	600	500	550	50600
FAIR METROIII	140	2000	2000	2000	280000
TOTAL:	407				556525
TYPE AVERAGE:	$1,367				
TOTAL, ALL:	4445				39639447
AVERAGE, ALL:	$8,918				

Appendix Table 6 (Continued)

SUMMARY OF REPLACEMENT COSTS YEAR: 1987

Type	Number	Share	Average
Twin Engine Narrow Body	1473	0.3314	$11,176
Three Engine Narrow Body	1169	0.2630	$5,372
Four Engine Narrow Body	172	0.0387	$10,619
Twin Engine Wide Body	121	0.0272	$32,897
Three Engine Wide Body	292	0.0657	$20,160
Four Engine Wide Body	152	0.0342	$23,196
20+ Seat Commuter	659	0.1483	$1,701
Less Than 20 Seat Commuter	407	0.0916	$1,367
TOTAL POPULATION:	4445	1	$8,918

Appendix Table 7

Air Carrier Aircraft Replacement Cost by Model - 1987
(average model values in current year $000)

Make/Sub-Model	Population	Bi-Annual Estimate of Aircraft Values 1	2	Annual Average	Extension
TWIN ENGINE NARROW BODY					
BAC111	45	$2175	$2126	$2150.5	$96773
BOE737	606	9563	9719	9641	5842446
BOE757	93	33830	33291	33560.5	3121127
DC9	679	9531	9941	9736	6610744
FOK28	50	6105	7320	6712.5	335625
TOTAL:	1473				16006714
TYPE AVERAGE :	$10,867				
THREE ENGINE NARROW BODY					
BOE727	1169	5395	5466	5430.5	6348255
TOTAL:	1169				6348255
TYPE AVERAGE:	$5,431				
FOUR ENGINE NARROW BODY					
BAE146	27	15750	14063	14906.5	402476
BOE707	35	1683	2473	2078	72730
DC8	110	9100	8808	8954	984940
TOTAL:	172				1460146
TYPE AVERAGE:	$8,489				
TWIN ENGINE WIDE BODY					
A300	34	22443	20589	21516	731544
A310	12	40000	30000	35000	420000
BOE767	73	40506	30000	35253	2573469
TOTAL:	119				3725013
TYPE AVERAGE:	$31,303				
THREE ENGINE WIDE BODY					
DC10	178	26313	28455	27384	4874352
L1011	114	19609	17971	18790	2142060
TOTAL:	292				7016412
TYPE AVERAGE:	$24,029				
FOUR ENGINE WIDE BODY					
BOE747	152	27662	27855	27758.5	4219292
TOTAL:	152				4219292
TYPE AVERAGE:	$27,759				

Appendix Table 7 (Continued)

Make/Sub-Model	Population	Bi-Annual Estimate of Aircraft Values 1	2	Annual Average	Extension
20+ SEAT COMMUTER					
ATR 42	8	$6850	$7400	$7125	$57000
CV580	58	1000	750	875	50750
CV600/640	31	625	500	562.5	17438
DHC-6	68	628	577	602.5	40970
DHC-7	38	3500	3250	3375	128250
DHC-8	29	5700	7750	6725	195025
EMB120	16	5200	5250	5225	83600
FAIR F-27	36	650	500	575	20700
FAIR METROII	119	434	434	434	51646
FH227	7	750	600	675	4725
FOKRF27	36	2263	1859	2061	74196
Lock L188	33	1110	903	1006.5	33215
NORD 262	13	300	300	300	3900
SAAB340	37	6100	6350	6225	230325
SHORT330	107	900	900	900	96300
SHORT360	3	2250	2250	2250	6750
NIHON YS11	36	1026	763	894.5	32202
TOTAL:	675				1126991
TYPE AVERAGE:	$1,670				
LESS THAN 20 SEAT COMMUTER					
BEECH99	95	715	652	683.5	64933
BEECH1900	61	2250	2000	2125	129625
BAE 31	6	2500	2500	2500	15000
CASA212	19	750	750	750	14250
EMB110	92	600	500	550	50600
FAIR METROIII	140	2000	2000	2000	280000
TOTAL:	413				554408
TYPE AVERAGE:	$1,342				
TOTAL, ALL:	4465				40457230
AVERAGE, ALL:	$9,061				

Appendix 7 (Continued)

SUMMARY OF REPLACEMENT COSTS YEAR: 1987

Type	Number	Share	Average
Twin Engine Narrow Body	1473	0.3299	$10,867
Three Engine Narrow Body	1169	0.2618	$5,431
Four Engine Narrow Body	172	0.0385	$8,489
Twin Engine Wide Body	119	0.0267	$31,303
Three Engine Wide Body	292	0.0654	$24,029
Four Engine Wide Body	152	0.0340	$27,759
20+ Seat Commuter	675	0.1512	$1,670
Less Than 20 Seat Commuter	413	0.0925	$1,342
TOTAL POPULATION:	4465	1	$9,061

Appendix Table 8

GENERAL AVIATION AIRCRAFT MAKE/MODEL 1987:
ACTIVE FLEET, AVERAGE VALUE AND FLEET HOURS

Make/Model	FAA-APO Type	Fleet	Average Value ($000)	Fleet Hours in 1987
AIRCOUPE415	1	1047	$7.2	59630
BELLANCA	1	626	23.7	70539
BOEING75	1	885	34.0	82287
CESSN120	1	512	7.8	33129
CESSN140	1	1619	8.1	144307
CESSN150	1	17449	10.6	3117436
CESSN188	1	1533	20.2	395392
GRTLK2T1	1	30	50.8	10190
GRUM164	1	1195	38.7	395417
GULSTAA1	1	978	9.1	76063
LUSCOM8	1	1284	7.7	59423
PIPER18	1	2974	17.0	429451
PIPER25	1	1035	21.7	215832
PIPER36	1	329	35.3	69060
PIPER38	1	1334	10.3	238712
PIPERJ3	1	2543	10.1	170530
VARG2150	1	126	19.0	11710
AERONCA15	2	123	9.4	6486
AYRESS2	2	783	44.0	284246
BEECH23	2	2201	17.0	291556
BEECH33	2	1550	50.6	151952
BEECH35	2	6082	28.8	689968
BEECH36	2	2199	98.5	360252
BELLANCA17	2	957	28.2	71226
BELLANCA1419	2	267	13.9	13165
BELLANCA7	2	3779	10.3	282791
CESSN170	2	1987	12.4	129277
CESSN172	2	23240	19.9	3494688
CESSN175	2	1184	10.3	143429
CESSN177	2	2546	21.9	275489
CESSN180	2	2466	21.8	242117
CESSN182	2	13046	30.1	1641911
CESSN185	2	1472	36.5	209599
CESSN195	2	280	17.6	15566
CESSN205	2	244	20.0	21611
CESSN206	2	2898	37.0	484593
CESSN207	2	314	48.5	181699
CESSN210	2	5816	47.4	770176
GULSTAA5	2	1607	19.6	187394
MAULEM4	2	161	14.3	8423
MAULEM5	2	443	23.9	41534
MAULEM6	2	69	34.4	6756
MOONEY20	2	6011	32.2	698255

Appendix Table 8 (Continued)

Make/Model	FAA-APO Type	Fleet	Average Value ($000)	Fleet Hours in 1987
NAVION	2	768	16.6	51440
PIPER22	2	3357	8.1	202796
PIPER24	2	2919	24.0	267012
PIPER28	2	21792	16.1	2876567
PIPER32	2	4069	43.6	600649
ROCKWELL112	2	629	26.3	67157
BEECH18	3	438	29.4	138645
BEECH50	3	155	31.7	28668
BEECH55	3	2047	52.4	393081
BEECH56	3	54	41.2	4650
BEECH58	3	1534	120.9	259044
BEECH60	3	400	132.5	62064
BEECH95	3	407	30.0	49848
CESSN310	3	2866	42.7	461658
CESSN320	3	298	30.1	22879
CESSN337	3	1084	28.9	177785
CESSN340	3	908	106.0	184867
PIPER23	3	2553	28.8	383261
PIPER30	3	1117	31.4	122675
PIPER31	3	1995	103.4	621591
PIPER44	3	327	45.6	149795
PIPER600	3	760	91.6	135594
BEECH65	4	91	41.8	7794
BEECH80	4	97	53.0	11153
CESSN401	4	226	54.0	50449
CESSN402	4	558	108.6	315149
CESSN404	4	98	264.3	45900
CESSN411	4	145	39.0	7211
CESSN414	4	776	143.6	211820
CESSN421	4	1018	108.6	234728
PIPER34	4	1770	53.6	393934
ROCKWELL500	4	235	77.6	60019
ROCKWELL560	4	43	24.0	4072
ROCKWELL680	4	127	46.0	18504
BEECH100	6	271	479.1	102841
BEECH200	6	857	680.8	278661
BEECH90	6	1115	426.9	333204
CESSN441	6	245	750.3	78279
MITSUB2	6	140	194.6	37694
PIPER31T	6	597	376.1	123558
ROCKWELL680T	6	89	111.9	14396
ROCKWELL690T	6	486	355.0	160287
SWER226	6	230	470.2	259673
SWER227	6	118	775.0	159449
SWER26	6	94	178.0	18686
DEHAVILL6	7	125	548.0	98301

Appendix Table 8 (Continued)

Make/Model	FAA-APO Type	Fleet	Average Value ($000)	Fleet Hours in 1987
EMBRAER110	7	116	705.0	273789
CESSN500	9	661	883.0	235838
CESSN650	9	97	4028.3	41843
FALCON10	9	138	1489.3	60374
FALCON20	9	205	1282.7	84582
HWKDH125	9	269	3613.6	108572
ISRL1121	9	89	255.3	21779
ISRL1124	9	216	1496.9	68077
LEAR23	9	45	200.8	10775
LEAR24	9	165	313.5	37647
LEAR25	9	260	545.0	87400
LEAR35	9	433	1459.6	200443
LEAR55	9	99	3357.7	45005
RKWLNA265	9	295	1134.5	164337
BELL47	11	740	40.8	316112
ENSTROMF28	11	400	48.2	122098
HILLER12	11	397	45.8	135305
HUGHES269SCH	11	504	53.7	129912
ROBINSONR22	11	243	50.1	72631
AEROSPAT316	12	48	166.7	14332
AEROSPAT350	12	244	242.5	120044
AEROSPAT355	12	126	394.8	68295
AGUSTA109	12	38	410.0	9428
BELL204	12	160	290.0	23490
BELL205	12	223	522.5	7954
BELL206	12	1921	220.8	987801
BELL212	12	102	781.7	42271
BELL214	12	18	3220.0	9042
BELL222	12	84	631.3	22255
BELL412	12	47	1530.0	49841
HUGHES369MDD	12	510	198.4	217398
SIKORSKY76	12	146	1692.5	58469

Appendix Table 9

Military Aircraft Values and Population 1988-92

Type/Model	Value ($000)	Population by Year 1988	1989	1990	1991	1992
TURBOJET/FAN - MULTIENGINE						
Boeing B-52	$15800	255	252	249	247	244
Boeing C135	2000	85	84	82	82	81
Boeing E3	125000	34	34	34	34	34
Boeing E4	175000	4	4	4	4	4
Boeing E6	130000	3	7	12	15	15
Boeing KC135A-Q	2000	446	396	345	295	244
Boeing KC135R	16700	179	227	275	323	371
Lockheed C5A	40000	75	75	74	73	72
Lockheed C5B	113000	45	50	50	50	50
Lockheed C141	15000	266	263	260	258	246
MDD C17	92000	0	1	3	8	19
MDD KC10	65000	59	58	58	57	56
Rockwell B1	133000	98	97	96	95	94
TURBOJET/FAN - OTHER (EXCLUDING FIGHTER/ATTACK)						
Boeing T43 (737)	7500	19	18	18	18	18
C20/21	3000	89	89	88	87	86
Cessna A/T-37	250	646	632	620	608	598
Cessna T47 (500)	750	24	23	23	23	23
Lockheed S3	9400	155	153	152	150	149
Lockheed SR71	24000	21	21	21	21	21
Lockheed TR-1	24000	35	35	35	35	35
Lockheed U2	24000	8	8	8	8	8
MDD A/T-4	1800	417	378	354	331	311
MDD C9	7000	53	52	51	51	51
Northrop T38	2000	782	773	764	755	747
Rockwell T2	500	177	164	148	120	84
TURBOJET/FAN - ATTACK/FIGHTER						
Fairchild A10	8000	644	637	631	625	619
GD F16A&B	12000	667	556	405	403	401
GD F16 ADS-D	17600	703	994	1284	1452	1617
GD F111	5600	408	404	400	396	392
Grumman A6	25000	576	580	579	576	547
Grumman F14	32700	450	454	465	476	496
MDD AV-8B	18300	142	170	198	216	229
MDD F4	3600	1498	1260	1053	921	813
MDD F15A-D	20000	809	808	801	793	784
MDD F15E	29000	49	91	131	171	211

Appendix Table 9 (Continued)

Type/Model	Value ($000)	Population by Year 1988	1989	1990	1991	1992
MDD F18	$21000	487	606	735	829	895
Northrop F5	5000	111	107	105	104	103
Vought A7	3000	742	707	682	650	640
TURBOPROP						
Beech C12	2250	271	275	280	280	280
Beech T34C	1200	345	348	344	347	349
Beech T44	750	56	55	55	54	54
Beech U21	500	116	114	113	112	111
Convair C131	550	24	17	16	14	13
DeHav DHC6-300	800	6	6	6	6	6
Grumman C1	500	12	10	8	7	6
Grumman C2	21000	43	50	49	49	48
Grumman E2C	35200	109	112	115	118	120
Grumman OV1	500	143	134	128	123	118
Lockheed C130A-E	7000	569	557	545	535	509
Lock C130 other	35000	225	233	234	232	229
Lockheed P3A&B	15000	158	148	139	129	121
Lockheed P3C	38100	248	251	254	251	249
Rockwell OV-10	500	128	127	126	124	124
PISTON ENGINE						
Beech T42	80	57	56	56	55	55
Beech U8F	45	48	48	47	47	46
Cessna O2	100	59	56	53	50	48
Cessna T41	20	43	41	39	37	35
ROTARY WING						
Bell AH1	2000	1005	1000	994	979	963
Bell AH1T&W	7000	74	82	82	91	100
Bell OH58A-C	600	1712	1667	1624	1572	1532
Bell OH58D	4300	115	135	135	134	134
Bell UH-1H	400	2917	2828	2744	2662	2582
Bell UH-1 M,N,V	500	653	645	639	633	626
Boeing CH46	3400	343	337	332	328	323
Boeing CH47	7900	391	398	414	423	445
Kamen HH2	6000	124	131	130	129	127
MDD AH64	8180	375	455	533	611	688
MDD OH6 (500)	200	367	363	359	355	351
Sikorsky SH-3	1000	251	245	240	235	231
Sikorsky CH53	5000	192	180	171	170	168
Sikorsky CH53E	15000	137	159	182	197	210
Sikorsky UH60	6100	1048	1168	1283	1403	1520

Appendix Table 10

Expanded Air Carrier Weight Penalty Model Factor Equations

Narrow Body, 2 Engine

$$F = 284.92 + .2206L + 1.338S + 14.48TU + 10.409TA - 4.4444*10^{-5}L^2 - 2.0832*10^{-3}S^2 - .1394TU^2 - 4.35*10^{-4}TA^2 - 6.08*10^{-4}LS + 4.973*10^{-3}LTU + 2.789*10^{-4}LTA + 3.41*10^{-2}STU + 1.898*10^{-3}STA - 1.557*10^{-2}TUTA$$

Narrow Body, 3 and 4 Engine

$$F = 123.632 + .2127L + 2.3636S + 33.6196TU + 21.638TA - 1.49*10^{-5}L^2 - 1.437*10^{-3}S^2 - .358TU^2 - .1403TA^2 + 2.913*10^{-4}LS + 6.163*10^{-3}LTU - 9.629*10^{-4}LTA + 1.212*10^{-2}STU + 7.125*10^{-3}STA - .448TUTA$$

Wide Body, 2 and 3 Engine

$$F = 4610.442 - .1537L + 2.0898S + 206.71TU + 162.224TA - 2.795*10^{-6}L^2 - 1.254*10^{-5}S^2 - 1.829TU^2 - 1.196TA^2 - 1.185*10^{-5}LS + 4.531*10^{-3}LTU + 3.657*10^{-3}LTA + 9.568*10^{-3}STU + 7.751*10^{-3}STA - 2.967TUTA$$

Wide Body, 4 Engine

$$F = 107.868 + 7.699*10^{-2}L + 5.342S + 34.822TU + 24.851TA - 4.281*10^{-7}L^2 - 2.062*10^{-3}S^2 - 8.74*10^{-2}TU^2 - 4.459*10^{-2}TA^2 + 5.953*10^{-5}LS - 3.879*10^{-4}LTU - 2.765*10^{-4}LTA - 2.675*10^{-2}STU - 1.917*10^{-2}STA - .1248TUTA$$

Where:

L = Average Block Length

S = Average Block Speed

TU = Tons Used

TA = Tons Available

Appendix Table 11

NUMBER OF ACCIDENTS RESULTING IN NON-AIRCRAFT PROPERTY DAMAGE BY PROPERTY TYPE, PHASE OF FLIGHT, AND USER CLASS *

PHASE: UNKNOWN	None	Resid	Resid Area	Comm'l Bldg	Vehicle	Airport Facil	Trees	Crops	Fence	Wires/ Poles	Other	ACCIDENTS
AIR CARRIER	19	1	1	0	2	2	2	1	0	2	1	27
AIR TAXI	70	3	0	1	0	3	19	3	2	3	3	104
GENERAL AVIATION	800	12	4	4	17	17	120	35	17	43	22	1058
TOTAL	889	16	5	5	19	22	141	39	19	48	26	1189

PHASE: ON GROUND	None	Resid	Resid Area	Comm'l Bldg	Vehicle	Airport Facil	Trees	Crops	Fence	Wires/ Poles	Other	ACCIDENTS
AIR CARRIER	8	0	0	1	6	2	0	0	0	0	1	18
AIR TAXI	27	1	0	1	2	1	0	0	0	2	6	40
GENERAL AVIATION	189	0	0	6	35	14	6	0	5	7	25	287
TOTAL	224	1	0	8	43	17	6	0	5	9	32	345

PHASE: TAKEOFF	None	Resid	Resid Area	Comm'l Bldg	Vehicle	Airport Facil	Trees	Crops	Fence	Wires/ Poles	Other	ACCIDENTS
AIR CARRIER	28	0	0	1	2	10	5	0	0	2	4	48
AIR TAXI	73	2	1	1	4	7	13	1	5	6	4	107
GENERAL AVIATION	1024	11	7	14	31	44	202	61	52	49	56	1496
TOTAL	1125	13	8	16	37	61	220	62	57	57	64	1651

* Horizontal summation may exceed number of accidents because of multiple citations per accident.

Appendix Table 11 (Continued)

NUMBER OF ACCIDENTS RESULTING IN NON-AIRCRAFT PROPERTY DAMAGE BY PROPERTY TYPE, PHASE OF FLIGHT, AND USER CLASS *

PHASE: APPROACH	None	Resid	Resid Area	Comm'l Bldg	Vehicle	Airport Facil	Trees	Crops	Fence	Wires/ Poles	Other	ACCIDENTS
AIR CARRIER	46	1	0	2	3	15	11	1	5	5	2	83
AIR TAXI	175	1	0	0	7	17	16	3	2	13	7	231
GENERAL AVIATION	2395	17	9	22	51	122	290	60	103	89	97	3180
TOTAL	2616	19	9	24	61	154	317	64	110	107	106	3494

PHASE: IN AIR	None	Resid	Resid Area	Comm'l Bldg	Vehicle	Airport Facil	Trees	Crops	Fence	Wires/ Poles	Other	ACCIDENTS
AIR CARRIER	2	0	0	0	0	0	1	0	0	0	0	3
AIR TAXI	12	0	0	0	1	1	3	0	0	0	0	17
GENERAL AVIATION	68	0	1	1	1	0	14	5	6	4	2	101
TOTAL	82	0	1	1	2	1	18	5	6	4	2	121

PHASE: TOTAL	None	Resid	Resid Area	Comm'l Bldg	Vehicle	Airport Facil	Trees	Crops	Fence	Wires/ Poles	Other	ACCIDENTS
AIR CARRIER	103	2	1	4	13	29	19	2	5	9	8	179
AIR TAXI	357	7	1	3	14	29	51	7	9	24	20	499
GENERAL AVIATION	4476	40	21	47	135	197	632	161	183	192	200	6122
TOTAL	4936	49	23	54	162	255	702	170	197	225	228	6800

* Horizontal summation may exceed number of accidents because of multiple citations per accident.

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39. Estimates of the percent of business and nonbusiness trips for each user group are employed as weights. See Gellman Research Associates, 1988, op. cit., for estimates of wage rates and trip purpose weights.

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Don Schilling rejects these conclusions in a rejoinder. He feels that a long term shift to inflation rates above historical levels is not out of the question. As such, Schilling argues that it is as reasonable to assume that inflation will offset a time value of money discount as it is to assume that the discount effect will be stronger. He therefore supports the "Alaskan" method for calculating compensation for lost income. (see Schilling, "Estimating the Present Value of ..." below).

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- "best practice" in which money wage growth for n years subsequent to a base year was projected from a trend line fitted by least squares to the n most recent past years, the discount rate used is the maximum interest on a bond portfolio maturing in n years, and
- "simplified compound-discount" which used only the geometric mean of the growth rate of earnings for n years times n discounted by the geometric mean of the long term interest rate for n years.

Schilling concluded that no method performed very well compared to the perfect foresight benchmark. The "Alaskan" method was, however, less inaccurate than the other two estimates. This method also has the virtue of simplicity. Even so, the simulation demonstrated that even the "Alaskan" method over- or underestimated the correct compensation by over 50% during various times over the historical period considered.

97. The prescribed OMB discount rate is meant to represent the average rate of return on private investment before taxes and after inflation (OMB Circular No. 8-94, p. 4). The rationale for using this discount rate is that government projects draw scarce investment resources from the private sector. The opportunity cost of such resources is the return on private investment. The discount rate is appropriately specified as being before tax because society loses the full value of the return including taxes even if the individual realizes only the after-tax return. One key problem with the OMB rate is that it assumes that all money drawn from the private sector would otherwise be invested. It could just as easily be consumed by individuals. The discount rate for consumption activities should be substantially lower than that for investment activities. The proper discount should be that interest rate which would just induce people to save. They would postpone current consumption in exchange for the ability to consume more in the future. For example, if the rate were 5

percent, then saving $1.00 for a year would result in having sufficient income to consume $1.05 worth of goods and services in the next year. The required rate of return for investments must be higher than that of consumption activities in order to compensate for the risk inherent in investment activities and for the cost of intermediaries (stock markets, banks, and other financial institutions).

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